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RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

FREE-SPINNING-TUNNEL TESTS OF A $\frac{1}{35}$-SCALE MODEL OF THE DOUGLAS XB-43 AIRPLANE

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

Spin tests have been performed in the Langley 20-foot free-spinning tunnel on a $\frac{1}{35}$-scale model of the Douglas XB-43 airplane. The spin and recovery characteristics were determined for several loading conditions of the airplane. The effects of installing a dorsal fin and of installing a ventral fin were investigated. Emergency escape of the crew was simulated and the stick and rudder-pedal forces necessary to effect recoveries on the airplane were determined.

The spin-recovery characteristics of the model were considered unsatisfactory. Results indicated that slow recoveries would be obtained when the rudder alone was reversed, and although recoveries were generally improved when the elevator was moved down in conjunction with reversal of the rudder, recoveries were generally still unsatisfactory. The results of the model tests indicate that satisfactory recovery characteristics can be obtained for all loadings and configurations of the airplane by installing an adequate ventral fin. Installation of a dorsal fin showed no effect on the spin and recovery characteristics of the model. It was found that, if the airplane has to be abandoned while in a spin, the crew members should leave from the outboard side of the cockpit. The results of the model tests indicate that the stick force necessary to move the elevator during a spin will be fairly high and that the rudder-pedal force necessary to reverse the model during a spin will probably exceed the physical capabilities of the pilot.

INTRODUCTION

In accordance with a request of the Air Materiel Command, Army Air Forces, tests were performed in the Langley 20-foot free-spinning tunnel to determine th spin and recovery characteristics of a $\frac{1}{35}$-scale model of the Douglas XB-43 airplane. The airplane which the model represented is a midwing, medium bomber propelled by two side-by-side jets issuing from the tail cone. The airplane normally has a crew of three, a pilot and copilot gunner seated side by side in the cockpit, and a bombardier in the fuselage just forward of the cockpit. For an alternate loading condition, Case IV, there is no bombardier in the airplane.

Tests were made to determine the effect of controls on the erect spin and recovery characteristics of the model in the clean condition for loading conditions designated by Douglas Aircraft Company, Inc., as gross-weight condition, Case I, and gross-weight condition, Case IV. Tests were also made with fuel expended for these gross-weight conditions. The effect of installing a dorsal fin, proposed by the Douglas Aircraft Company, Inc., and designated as a false fin, was investigated. Tests were also made with a ventral fin installed on the model, and emergency escape of the crew of the airplane was simulated.

An estimation of the stick and rudder-pedal forces required to move the controls for recovery was made from measurements of the tension in the elevator and rudder cables.

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 fuselage reference line)

m mass of airplane, slugs

ρ air density, slugs per cubic foot

μ relative density of airplane $\left(\frac{m}{\rho S b}\right)$

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

α angle between thrust 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, absolute value of 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 helix angle.)

APPARATUS AND METHODS

Model

The $\frac{1}{35}$-scale model of the Douglas XB-43 airplane used for the tests was constructed, in accordance with drawings furnished by the

Army Air Forces, and prepared for testing by the Langley Laboratory. A three-view drawing of the model as tested is given in figure 1. Dimensional characteristics of the airplane represented by the model are given in table I. Photographs of the model as tested in the free-spinning tunnel are shown in figure 2. The dorsal fin and the ventral fin tested on the model are shown in figures 3 and 4, respectively.

The model was ballasted by means of lead weights to obtain dynamic similarity to the airplane at an arbitrary altitude of 20,000 feet (ρ = 0.001267 slug per cubic foot). The weight, moments of inertia, and center-of-gravity location of the airplane were obtained from data furnished by Douglas Aircraft Company, Inc. A remote-control mechanism was installed in the model by the Langley Laboratory and was used to actuate the controls for recovery tests and to release a $\frac{1}{35}$-scale model of a man for emergency-escape tests. Sufficient moments were exerted on the controls during recovery attempts to reverse them fully and rapidly.

A $\frac{1}{35}$-scale model of a 6-foot man was used to simulate crew members for the emergency-escape tests and was built at the Langley Laboratory and weighted by means of lead weights to represent a man with a parachute (combined weight of 200 pounds) at an altitude of 20,000 feet.

Wind-Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which, in general, is similar to that described in reference 1 for the Langley 15-foot free-spinning tunnel except that the model-launching technique has been changed. With the controls set in position, rotation is imparted to the model as it is launched by hand into the vertically rising air stream. After a number of turns the model assumes its spin attitude and is maintained at a specified level in the tunnel by adjusting the airspeed so that the model drag equals its weight. The model is shown spinning in the Langley 20-foot free-spinning tunnel in figure 5. After a number of turns of the established spin have been photographed and timed, a recovery attempt is made by moving one or more controls by means of the remote-control mechanism; if recovery is effected, the model dives or glides into a safety net. The spin data obtained from the tests are then converted to corresponding full-scale values by methods described in reference 1.

In accordance with standard spin-tunnel procedure, tests were performed to determine the spin and recovery characteristics for the normal control configuration for spinning (elevator full up, ailerons neutral, and rudder full with the spin) and for other aileron-elevator combinations including neutral and maximum settings of the control surfaces for various model conditions. Recovery was generally attempted by reversal of the rudder from full with the spin to full against the spin. Tests were also performed to determine how critically dependent recovery from the normal control configuration for spinning was upon small variations in control deflections. For these tests, the elevator was set at only two-thirds full up and the ailerons were set one-third with or one-third against the spin, depending upon the direction conducive to slower recoveries. Recovery from this spin was attempted by reversing the rudder from full with to two-thirds against the spin either alone or in conjunction with movement of the elevator. This control configuration and movement is referred to herein as the "criterion spin." The turns for recovery were measured from the time the controls were moved until the spinning rotation ceased. The criterion for a satisfactory recovery from a spin in the spin tunnel has been adopted as 2 turns or less based primarily on the loss of altitude of the airplane during the recovery and subsequent dive. The recovery characteristics for a given loading condition of the model are considered satisfactory, however, when satisfactory recoveries are obtained within $2\frac{1}{4}$ turns from the criterion spin for the aileron deflection conducive to slow recoveries either by reversal of the rudder alone or by combined rudder and elevator movement. Movement of the elevator to only one-third down in conjunction with rudder reversal is considered desirable, but recovery characteristics are considered satisfactory when recovery is obtained from the criterion spin within $2\frac{1}{4}$ turns by rudder reversal combined with movement of the elevator to full down.

For recovery attempts in which the model struck the safety net before recovery could be effected because of the oscillatory nature of the spin, or because of the high rate of descent, the number of turns the model made from the time the controls were applied for recovery until the model struck the safety net was recorded. This number indicated that the model required more turns to recover than the number recorded, for example >3. A >3-turn recovery, however, does not necessarily indicate an improvement over a >5-turn recovery. If the model stopped rotating without movement of the controls after being launched with initial spin rotation with the rudder set for a spin, the condition was recorded as "no spin," In the determination of the full-scale stick and rudder-pedal forces necessary to effect satisfactory recovery from a spin, the tension in the rubber band which pulls the rudder from with to against the spin or the elevator from up to down was adjusted to represent a known hinge moment about the respective hinge lines. Recovery tests were then run. The tension in the rubber band was reduced systematically until the turns for recovery began to increase. The model rudder or elevator hinge moment at this point is considered indicative of the force that should be applied to move the controls for recovery on the airplane and was converted to corresponding full-scale rudder-pedal and stick forces at the equivalent altitude at which the tests were run.

As previously mentioned, emergency escape of the crew during a spin was simulated. For the tests, a dummy crew member was released from the inboard side (right side in a right spin) and from the outboard side of the fuselage at the cockpit by actuating the remote-control mechanism when the model was in a typical flat spin and when it was in a typical steep spin. The path of the dummy after release was observed. Tests were made to simulate emergency escape only from the cockpit inasmuch as the information available on the airplane indicated that all crew members enter and leave the airplane through the cockpit.

PRECISION

The model test results presented 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 film records; ±1/2 turn when obtained visually }

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 model and airplane spin results (references 1 and 2) 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 with 5° to 10° more outward sideslip than did the corresponding airplanes. The comparison made in reference 2 for 20 airplanes showed that 80 percent of the model recovery tests predicted satisfactorily the corresponding airplane recovery characteristics and that 10 percent were optimistic and 10 percent were pessimistic as regards the airplane recovery characteristics.

Little can be stated about the precision of the emergency-escape tests as no comparable full-scale data are available. It is considered, however, that when the dummy is observed to clear all parts of the model by a fairly large margin after being released, the crew members may, if it becomes necessary, jump from the spinning airplane without being struck.

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

	Gross-weight condition Case I	Gross-weight condition Case IV
Weight, percent	1 low to 0	1 low to 2 high
Center-of-gravity location, percent $\bar{c}$	2 forward of normal to 0	0 to 1 rearward of normal
I_X, percent	1 low to 2 high	1 high to 6 high
I_Y, percent	1 low to 3 high	1 low to 7 high
I_Z, percent	6 low to 1 low	1 low to 4 high

The limits of accuracy of the measurements of the mass characteristics were as follows:

Weight, percent . . . . ±1

Center-of-gravity position, percent $\bar{c}$ . . . . ±1

Moments of inertia, percent . . . . ±5

The controls were set with an accuracy of ±1°.

TEST CONDITIONS

Numerous conditions of the airplane were considered in the preparation of the test program for the model. Spin tests were conducted on the model, however, only for the extremes in loading conditions possible on the airplane inasmuch as it appeared that the results for other loading conditions possible on the airplane would be similar to those for the conditions tested. The conditions tested on the model are listed in table II and are briefly described as follows (weights are full scale): Gross-weight condition for Case I included 1370 gallons of fuel (total) carried internally in the wings, two 2000-pound bombs in the forward bomb bay, and two 2000-pound bombs in the rear bomb bay; gross-weight condition for Case IV included only 317 gallons of fuel (total) carried internally in the wings, had all bombs removed, and had 4424 pounds of fuel and tanks installed in the rear bomb bay. For both conditions, Case I and Case IV, tests were also made on the model simulating all wing fuel expended.

Mass characteristics and inertia parameters for various loading conditions possible on the airplane are shown in table III. The weight, center-of-gravity location, and moments of inertia for the loadings tested on the model have been converted to full-scale values and are also given in table III. The inertia parameters for both the model and the airplane have been plotted in figure 6. A full discussion of the significance of this figure may be found in reference 3.

The tail-damping power factors of the airplane for the tail configurations tested are presented in table IV. The tail-damping power factors were computed by the method described in reference 4.

The normal maximum control deflections used were:

Rudder, degrees	20 right, 20 left
Elevator, degrees	25 up, 10 down
Ailerons, degrees	16 up, 16 down

The intermediate control deflections used were:

Rudder, two-thirds deflected, degrees	$13\frac{1}{3}$
Aileron, one-third deflected, degrees	$5\frac{1}{3}$ up, $5\frac{1}{3}$ down
Elevator, deflected two-thirds up, degrees	$16\frac{2}{3}$
Elevator, deflected one-third down, degrees	$3\frac{1}{3}$
Elevator, deflected one-half down, degrees	5
Elevator, deflected two-thirds down, degrees	7

All tests were made with the cockpit closed, the landing gear retracted, and the flaps neutral.

RESULTS AND DISCUSSION

The results of the model tests are presented in charts 1 to 5 and in tables V and VI.

Because of inadvertent damage to the model during testing, the asymmetry of the model changed occasionally during the test program. Test results are presented for the direction of spin which gave conservative results (slower recoveries). Inasmuch as there was only a slight difference in the results obtained for the two directions of spin, however, it is considered that the results presented are representative of those that will be obtained on the airplane. The results are arbitrarily presented on the charts in terms of right spins.

Erect Spins

Gross-weight condition, Case I.- The results of erect spin tests of the model loaded to represent gross-weight condition Case I are presented in chart 1. The model loading condition is represented by point 1 in table III and figure 6. The spins obtained were generally oscillatory in pitch and roll. From the flat portion of the spin (angle of attack of approximately 40°), the spin gradually steepened and the rate of rotation increased until an angle of attack of approximately 20° was reached, when the model abruptly whipped back to the flat attitude. The rate of rotation then gradually decreased to complete a cycle of oscillation. In general, 6 to 10 turns were required to complete the cycle of oscillation.

Although recovery by rudder reversal was unsatisfactory from the spins obtained at the normal and the criterion spin configurations, satisfactory recoveries were obtained from either the flat or steep portion of these spins by moving the elevator to one-third down in conjunction with reversal of the rudder from full with to two-thirds against the spin. Deflecting the ailerons against the spin (stick left in a right erect spin) had a beneficial effect on recovery whereas deflecting the ailerons with the spin showed a somewhat adverse effect on recovery. The model would not spin for any aileron setting when the elevator was set full down even though the rudder was set for the spin.

The results of the tests for this loading condition are in agreement with past spin-tunnel experience (see reference 3); that is, moving the elevator down in conjunction with rudder reversal expedited recovery and aileron-against settings were favorable.

Gross-weight condition, Case I, with wing fuel expended.- The test results obtained with the model ballasted to represent gross-weight condition, Case I, with wing fuel expended are presented in chart 2. This loading condition is represented by point 2 in table III and figure 6. For this loading condition, the model spun at a steep attitude without the characteristic pitching oscillations obtained for gross-weight condition, Case I, with fuel in the wings. Based on spin-tunnel experience, this change may be attributed to the removal of weight from the wings of the model. The recovery characteristics were considered unsatisfactory by rudder reversal alone or by simultaneous rudder and elevator reversal, on the basis of the results for the criterion spin.

Gross-weight condition, Case IV.- The test results obtained with the model ballasted to represent gross-weight condition, Case IV, are presented in chart 3. This loading condition is represented by point 5 in table III and figure 6. For the criterion-spin configuration and for all elevator full-up configurations, the model spun with a large radius and a low rate of rotation and oscillated in pitch between angles of attack of approximately 55° and 35°. Approximately 1 cycle of the pitching oscillation was completed during each revolution of the spin. Rudder reversal stopped the spin rotation in $2\frac{1}{2}$ turns or less for the previously mentioned spins, but the model remained at a stalled attitude thereafter (angle of attack approximately 40°). Rapid recoveries followed by steep dives were obtained from these configurations, however, when the elevator was moved down in conjunction with reversal of the rudder. It was necessary to move the elevator to one-third down in conjunction with rudder reversal in order to cause the model to pitch down into a steep dive after the spin rotation stopped when the ailerons were neutral or against the spin. For the criterion spin, it was necessary to move the elevator to two-thirds down in conjunction with rudder reversal in order to effect rapid recovery terminating in a steep dive. The rapid recoveries obtained by simultaneous rudder and elevator movement are attributed to the dynamic action of the elevator inasmuch as recoveries from elevator-down spins were generally unsatisfactory when the rudder alone was reversed to full against the spin. The spins obtained when the elevator was set at neutral or down were generally similar to the oscillatory spins previously described for gross-weight condition, Case I.

Gross-weight condition, Case IV, with wing fuel expended.- The results obtained with the model ballasted to simulate gross-weight condition, Case IV, with wing fuel expended are presented in chart 4. This loading is represented by point 6 in table III and figure 6. The spins obtained for this condition had large radii and low rates of rotation. Rudder reversal stopped the spin rotation for the control configurations tested but as for Case IV with fuel in the wings, the model remained at a stalled attitude. Movement of the elevator to one-third down in conjunction with reversal of the rudder effected rapid recoveries followed by steep dives from some of these spins, but for the criterion spin, movement of the elevator either partially or full down in conjunction with rudder reversal was not sufficient to insure good recovery.

Modifications

Dorsal fin installed.- The results of model spin tests with a dorsal fin (fig. 3) installed on the model are presented in table V. The tests were performed for gross-weight condition, Case I, and gross-weight condition, Case IV. Installation of the dorsal fin had no appreciable effect on the recovery characteristics of the model for the loading conditions tested.

Ventral fin installed.- Tests were made with the ventral fin shown in figure 4 installed on the model in an attempt to improve the recovery characteristics for gross-weight condition, Case IV, with fuel in the wings and for gross-weight conditions, Case I and Case IV, with fuel expended. The results of these tests are presented in chart 5 and table VI and show a favorable effect of installing the ventral fin inasmuch as satisfactory recovery characteristics were now indicated for these loading conditions. For gross-weight condition, Case I, with wing fuel expended, recovery was satisfactory from the criterion spin by rudder reversal alone or by moving the elevator down in conjunction with rudder reversal out for gross-weight condition, Case IV, it was necessary to move the elevator to one-half down in conjunction with rudder reversal in order to obtain satisfactory recovery. Based on these results, it appears that when a ventral fin is installed, recovery will be satisfactory by the normal control manipulation (rapid full-rudder reversal followed 1/2 turn later by movement of the stick well forward of neutral for all loading conditions of the airplane.)

Installation of the ventral fin shown in figure 4 may conflict with ground clearance considerations and thus may not be desirable for installation on the airplane. Analysis indicates that an effect on recovery characteristics equivalent to that provided by the installation of the ventral fin may be procured by moving the horizontal tail surfaces up approximately 50 inches, full-scale, and this revision may be made in lieu of installing a ventral fin.

Landing Condition

The landing condition (landing gear extended and landing flaps deflected) was not tested on the model inasmuch as it is required that airplanes demonstrate satisfactory recoveries in the landing condition from only a 1-turn spin. At the end of 1 turn, the airplane is usually still in an incipient spin from which recoveries are more readily obtained than from fully developed spins.

An analysis of the results of tests performed on models of many airplanes to determine the effect of flaps and landing gear indicates that the Douglas XB-43 airplane will probably recovery satisfactorily from a 1-turn incipient spin in the landing condition, but that recoveries from fully developed spins in the landing condition will probably 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 in order to avoid entering a fully developed spin from which recovery will probably be unsatisfactory.

Inverted Spins

The inverted-spin characteristics of the model were not investigated inasmuch as it appeared that the inverted-spin characteristics could be estimated on the basis of the results of inverted-spin tests of a model of a dimensionally similar airplane (Douglas XB-42) and on the conclusions of reference 5, which is a compilation of the results of inverted-spin tests conducted on 44 models of different design characteristics. Inasmuch as the results of the inverted-spin tests of the Douglas XB-42 are in general agreement with the conclusions of reference 5, and because of the dimensional similarity of the two airplanes, it appears that the inverted-spin recovery results for the Douglas XB-42 may be considered applicable in determining the inverted spin-recovery characteristics of the Douglas XB-43 airplane. It thus appears that if the Douglas XB-43 airplane should inadvertently enter an inverted spin, satisfactory recoveries can be obtained by reversing the rudder fully and rapidly followed by moving the stick to neutral laterally and longitudinally.

Recommended Recovery Technique

Based on the results of model tests, the following technique is recommended for recovery from spins for all loadings and configurations of the airplane:

Erect spins.- Hold the stick full back and laterally neutral and briskly reverse the rudder from full with to full against the spin. Approximately 1/2 turn after full rudder reversal, briskly move the stick well forward of neutral to pitch the airplane down into a recovery dive. Care should be exercised to maintain the ailerons neutral inasmuch as the effect of aileron deflections on recovery changes as the wing fuel is expended. In moving the stick forward, care should be taken to avoid excessive acceleration in the ensuing recovery dive.

Landing condition.- Upon entering a spin in the landing condition, the flaps should be retracted immediately and recovery attempted by the previously recommended recovery technique.

Inverted spins.– For recoveries from inverted spins, the rudder should be reversed fully and rapidly followed by moving the stick to neutral, laterally and longitudinally.

Emergency Escape During a Spin

Tests made to simulate emergency escape of the crew from the spinning airplane showed that when the model crew member was released from the outboard side of the fuselage (left side in a right spin) for either flat or steep spins, it traveled outboard and passed down under the outboard wing approximately at the midpoint of the wing semispan by a safe margin. When the dummy was released from the inboard side of the fuselage for either a flat or steep spin, however, it traveled rearward and parallel to the fuselage and went near, or was struck by either the vertical or the horizontal tail surfaces. Based on the results presented herein, it is recommended that the crew members leave from the outboard side of the cockpit if ever it becomes necessary to escape from the airplane during a spin.

Control Forces

For the regular test program, as previously mentioned, sufficient hinge moment was applied to the rudder and elevator to reverse them fully and rapidly and the discussion so far has been based on the effectiveness of the controls alone without regard to the forces required to move them. A few tests were made to determine the minimum stick and rudder pedal forces required to move the controls for recovery. The results indicated that the full-scale stick force will be fairly high and that the rudder pedal force will probably exceed the physical capability of the pilot; the stick force will be approximately 100 pounds and the rudder pedal force will be approximately 2000 pounds. Because of the lack of detail in the balance of the model control surfaces, of inertia mass balance effects, and of scale effect, these results are considered only qualitative indications of the actual forces that may be experienced.

The results of the control force tests indicate that in order to fully reverse the controls in a spin, trim tabs or some other suitable balance or booster arrangement may be necessary.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of spin tests of a $\frac{1}{35}$-scale model of the Douglas XB-43 airplane, the following conclusions and recommendations regarding the spin and recovery characteristics of the airplane at a spin altitude of 20,000 feet are made:

1. The spins will, in general, be oscillatory in pitch and roll and the recovery characteristics will be unsatisfactory.

2. Installation of an adequate ventral fin will provide satisfactory recovery characteristics for all configurations and loadings of the airplane. For recovery, it is recommended that the stick be held laterally neutral, the rudder be moved rapidly and fully against the spin and, 1/2 turn later the stick be briskly moved forward of neutral, maintaining it laterally neutral.

3. Installation of the proposed dorsal fin will have no appreciable effect on the spin and recovery characteristics of the airplane.

4. If it should become necessary to abandon the airplane during a spin, it is recommended that the crew leave from the outboard side of the cockpit.

5. The stick force necessary to move the elevator during a spin will be fairly high and the rudder pedal force necessary to reverse the rudder during a spin will probably exceed the physical capabilities of the pilot. Some suitable trim tabs or a control booster system will be necessary to decrease these forces.

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REFERENCES

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

2. Seidman, Oscar, and Neihouse, A. I.: Comparison of Free-Spinning Wind-Tunnel Results with Corresponding Full-Scale Spin Results. NACA MR, Dec. 7, 1938.

3. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation on the Recovery from a Spin. NACA ARR, Aug. 1942.

4. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN No. 1045, 1946.

5. MacDougall, George F., Jr.: Tests of Inverted Spins in the NACA Free-Spinning Tunnels. NACA ARR No. 3L02, 1943.

SUPPLEMENTARY REFERENCES

1. Douglas Aircraft Co., Inc. Drawings Nos.:

   5315358: $\frac{1}{35}$-Size MX 475 Spin Model - Fuselage

   5315359: $\frac{1}{35}$-Size MX 475 Spin Model - Wing and Horizontal Surfaces

   2315393: $\frac{1}{35}$-Size MX 475 Spin Model - False Fin

2. Douglas Aircraft Company, Inc. let. to ATSCLO August 17, 1945, MJW:rmo.

3. Douglas Aircraft Company, Inc. let. to ATSCLO July 4, 1945, CWF:mo.

TABLE I.— DIMENSIONAL CHARACTERISTICS OF THE

DOUGLAS XB-43 AIRPLANE

Length over all, ft	51.42
Wing:	
Span, ft	71.30
Area, sq ft	578.00
Root-chord incidence, deg	2.00
Tip-chord incidence, deg	3.30
Aspect ratio	8.75
Taper ratio	.332
Sweepback of leading edge of wing, deg	10.70
Dihedral of wing, deg	4.00
Mean aerodynamic chord, in.	103.11
Leading edge of mean aerodynamic chord rearward of leading edge of root chord, in.	33.60
Ailerons:	
Chord (rearward of hinge line), percent of wing chord	22.00
Area (rearward of hinge line), percent of wing area	5.00
Span, percent of wing span	15.15
Horizontal tail surfaces:	
Total area, sq ft	146.30
Span, ft	25.00
Elevator area rearward of hinge line, sq ft	36.10
Distance from gross-weight condition, Case I center-of-gravity location to elevator hinge line, ft	23.77
Vertical tail surfaces:	
Total area, sq ft	71.20
Total rudder area, sq ft	26.14
Distance from gross-weight condition, Case I center-of-gravity location to bottom of rudder hinge line, ft	23.82

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TABLE II.— CONDITIONS TESTED ON THE $\frac{1}{35}$-SCALE MODEL

OF THE DOUGLAS XB-43 AIRPLANE

[Erect Spins; Flaps and Landing Gear Retracted]

No.	Gross-weight condition	Special tests	Modification	Figure	Data on Table	Data on Chart
1	Case I	None	None	1,2		1
2	Case I with wing fuel expended	None	None	1,2		2
3	Case IV	None	None	1,2		3
4	Case IV with wing fuel expended	None	None			4
5	Case I	None	Dorsal fin	3	V	
6	Case I with wing fuel expended	None	Ventral fin	4		5
7	Case IV	None	Dorsal fin	3	V	
8	Case IV	None	Ventral fin	4	VI	
9	Case IV with wing fuel expended	None	None	4	VI	
10	Case IV	Pilot escape	None			

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TABLE III.– MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR VARIOUS LOADINGS POSSIBLE ON THE DOUGLAS XB-43 AIRPLANE AND FOR THE LOADINGS TESTED ON THE $\frac{1}{35}$-SCALE MODEL

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

No.	Gross-weight condition	Weight (lb)	μ 20,000 (ft)	μ sea level	Center-of-gravity location $x/\bar{c}$	Center-of-gravity location $z/\bar{c}$	Moments of inertia about center of gravity I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)	Inertia parameters $\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
						Airplane Values						
1	Case I	38,791	23.10	12.34	0.302	−0.017	125,700	72,480	187,800	87×10^{-4}	-189×10^{-4}	102×10^{-4}
2	Case I with wing fuel expended	30,570	18.19	9.69	.268	.001	68,568	71,678	130,195	−6	−121	127
3	Case II	33,109	19.80	10.51	.351	−.066	124,200	64,820	181,100	114	−223	109
4	Case III	32,605	19.44	10.36	.406	−.072	123,800	60,790	177,400	123	−228	105
5	Case IV	28,250	16.84	8.98	.451	−.059	96,810	60,960	149,700	81	−200	119
6	Case IV with wing fuel expended	26,335	15.70	8.40	.436	−.046	48,060	60,440	101,340	−30	−99	129
						Model values						
1	Case I	38,510	22.90	12.00	0.296	0.056	123,533	76,760	182,213	77×10^{-4}	-174×10^{-4}	97×10^{-4}
2	Case I with wing fuel expended	30,101	17.95	9.54	.259	.000	71,280	74,386	130,226	−7	−118	125
5	Case IV	28,479	16.97	9.04	.449	.021	96,430	59,560	146,100	82	−194	112
6	Case IV with wing fuel expended	26,863	15.66	8.35	.455	.0544	46,507	65,187	100,267	−45	−85	130

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TABLE IV.— TAIL-DAMPING POWER FACTORS FOR THE ORIGINAL TAIL DESIGN AND FOR THE TAIL MODIFICATIONS TESTED ON THE $\frac{1}{35}$-SCALE MODEL OF THE DOUGLAS XB-43 AIRPLANE

No.	Gross-weight condition	Revision	Tail-damping ratio	Unshielded rudder volume coefficient	Tail-damping power factor
1	Case I	None	0.0174	0.00217	0.000038
2	Case IV	None	.0154	.00206	.000032
3	Case I	Dorsal fin	.0174	.00217	.000038
4	Case IV	None	.0154	.00206	.000032
5	Case IV	Ventral fin	.0257	.01520	.000391
6	Case I with wing fuel expended	None	.0179	.00219	.000039
7	Case I with wing fuel expended	Ventral fin	.0302	.01587	.000479
8	Case IV with wing fuel expended	None	.0157	.00207	.000033
9	Case IV with wing fuel expended	Ventral fin	.0260	.01530	.000398

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TABLE V.– SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{35}$–SCALE MODEL

OF THE DOUGLAS XB-43 AIRPLANE WITH A DORSAL FIN INSTALLED

[Loading as indicated; recovery attempted by full rapid rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]

	Gross-weight condition, Case I	Gross-weight condition, Case IV		
Ailerons	With the spin	Neutral	With the spin	
	1/3 with		1/3 with	Full with
Elevator	2/3 up	Full up	2/3 up	Full up
α	[a]23 44	[a]43 54	[a]47 55	[a]51
ϕ	7U 4D	4U 15D	5D	8D 16D
Ω (rps)	.30	.11	.12	.11
V (fps)	360 387	278	269	278
Turns for Recovery	[b]$>3\frac{1}{2}$, [b]>5	[d]	[b,d]	[d]
	[c]$\frac{1}{2}$, [c]$\frac{3}{4}$	[e,f]$\frac{3}{4}$ [e,f]$1\frac{1}{4}$	[f,g]1 [f,g]1	[f,h]$\frac{1}{2}$ [f,h]$\frac{1}{2}$

[a]Oscillatory spin. Average value or range of values given.
[b]Recovery attempted by reversing the rudder from full with to 2/3 against the spin.
[c]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.
[d]Spinning rotation stopped in $2\frac{1}{2}$ turns or less after moving the rudder against the spin. Model then glided across the tunnel at a stalled attitude.
[e]Recovery attempted by simultaneously reversing the rudder from full with to full against the spin and the elevator from full up to 1/3 down.
[f]Model recovered in steep dive.
[g]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and the elevator from 2/3 up to 2/3 down.
[h]Recovery attempted by simultaneously reversing the rudder from full with to full against the spin and the elevator from full up to full down.

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TABLE VI.– SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{35}$-SCALE

MODEL OF THE DOUGLAS XB-43 AIRPLANE WITH

A VENTRAL FIN INSTALLED

[Loading as indicated; recovery attempted by full rapid rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins): right erect spins]

	Gross-weight condition, Case IV	Gross-weight condition, Case IV, with wing fuel expended	
Ailerons	With the spin 1/3 with	Against the spin 1/3 against	Neutral
Elevator	2/3 up	2/3 up	Full up
α	$^{a}51$	$^{a}45$(approx)	$^{a}46$
ϕ	5D	--	12D
Ω (rps)	.166	--	.17
V (fps)	276	269(approx)	269(approx)
Turns for recovery	^{b,c}	$^{d,e,g}1/4$ $^{d,e,g}1/2$	$^{g,h}3/4$ $^{g,h}1$
	$^{d,e}>3$		
	$^{f,g}3/4$ $^{e,f}1/2$	$^{g,i}1/4$ $^{g,i}1/2$	

[a] Wide radius spin with low rate of rotation.

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

[c] Spinning rotation stopped in 1 turn or less after reversing rudder to against the spin, model then glided across the tunnel at a stalled attitude.

[d] Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.

[e] Visual estimate.

[f] Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from full up to 1/2 down.

[g] Model recovered in a steep dive.

[h] Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from full up to 1/3 down.

[i] Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from 2/3 up to full down (10°).

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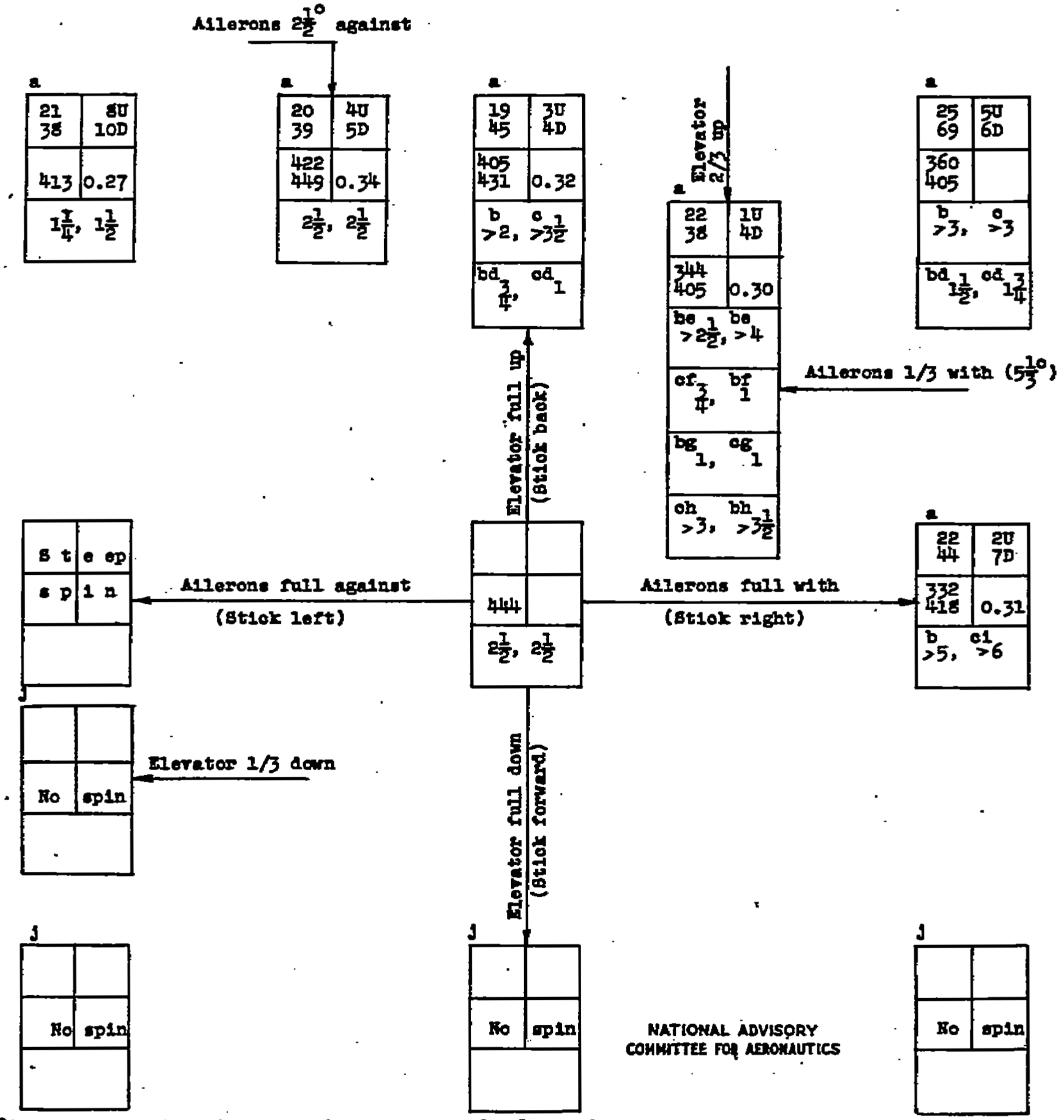
CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{35}$-SCALE MODEL OF THE DOUGLAS XB-43 AIRPLANE IN GROSS WEIGHT CONDITION, CASE I

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



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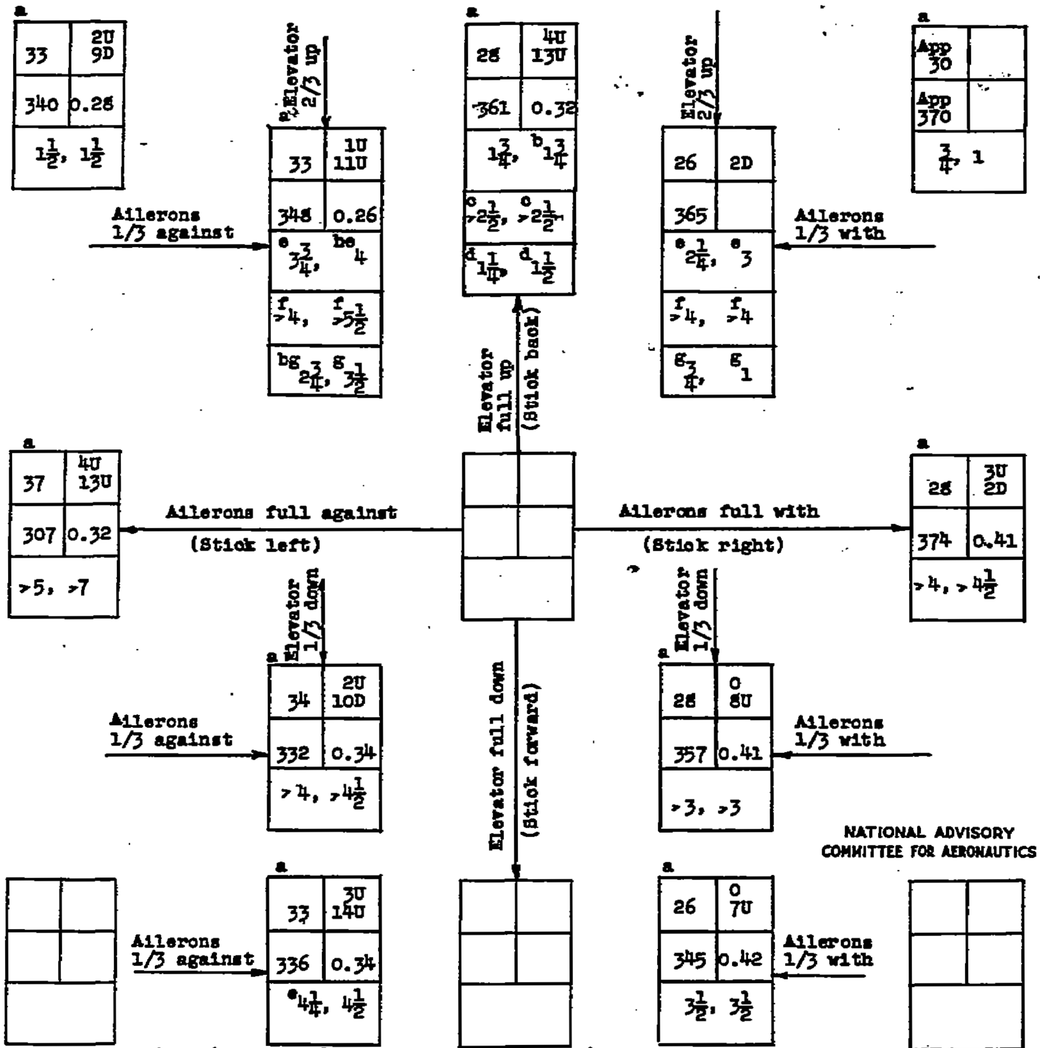
[a]Oscillatory spin. Average value or range of values given.
[b]Recovery attempted from steep phase of oscillation.
[c]Recovery attempted from flat phase of oscillation.
[d]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and the elevator from full up to 1/3 down.
[e]Recovery attempted by reversing the rudder from full with to 2/3 against the spin.
[f]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.
[g]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and the elevator from 2/3 up to neutral.
[h]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and the elevator from 2/3 up to 2° up.
[i]Visual estimate.
[j]Model went into steep dive after launching rotation stopped.

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.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{32}$-SCALE MODEL OF THE DOUGLAS XB-43 AIRPLANE IN GROSS WEIGHT CONDITION CASE I WITH WING FUEL EXPENDED

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



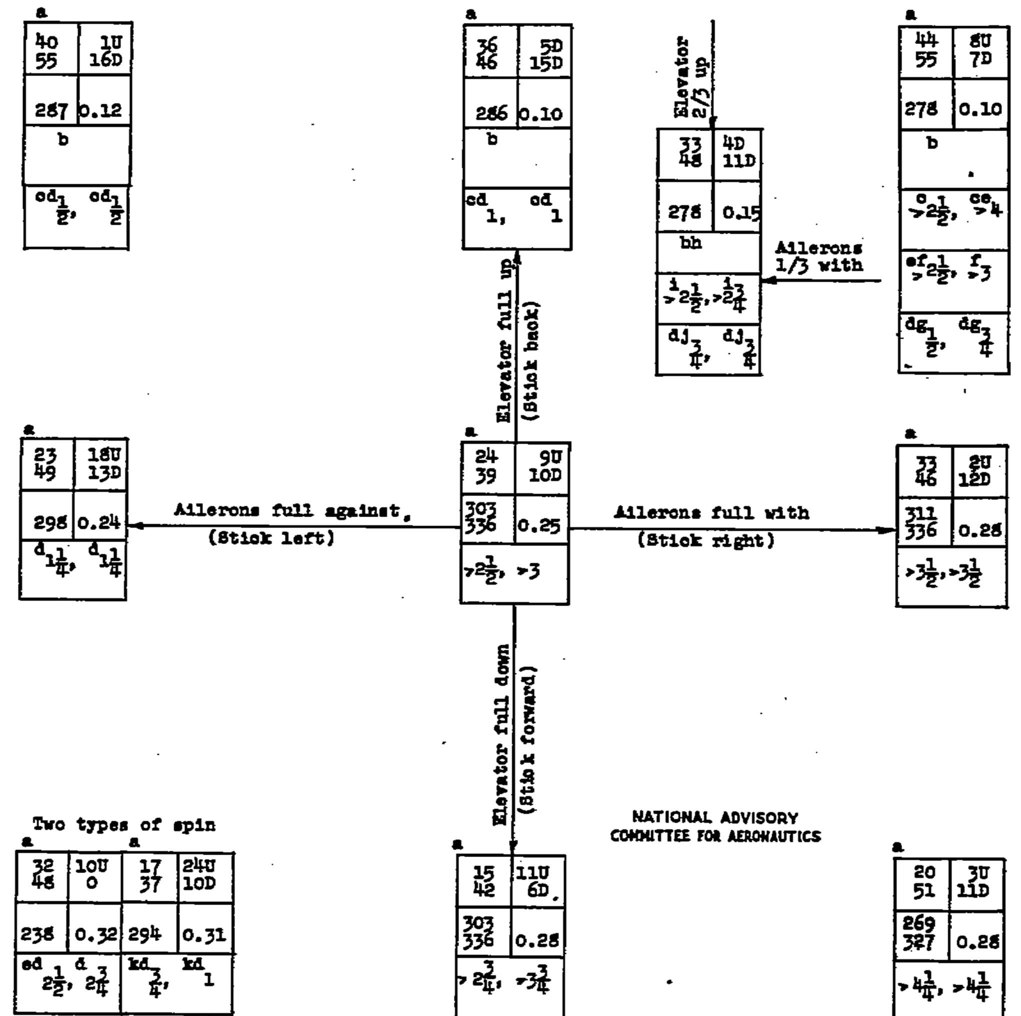
[a]Oscillatory spin. Average value or range of values given.
[b]Visual estimate.
[c]Recovery attempted by simultaneously reversing the rudder from full with the spin to full against the spin and the elevator from full up to 1/3 down.
[d]Recovery attempted by simultaneously reversing the rudder from full with the spin to full against the spin and the elevator from full up to full down.
[e]Recovery attempted by reversing the rudder from full with the spin to 2/3 against the spin.
[f]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.
[g]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator 2/3 up to full 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	

CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{35}$-SCALE MODEL OF THE DOUGLAS XB-43 AIRPLANE IN GROSS WEIGHT CONDITION CASE IV

[Loading point 5 on table III and figure 6; recovery attempted by full rapid rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins); right erect spins]



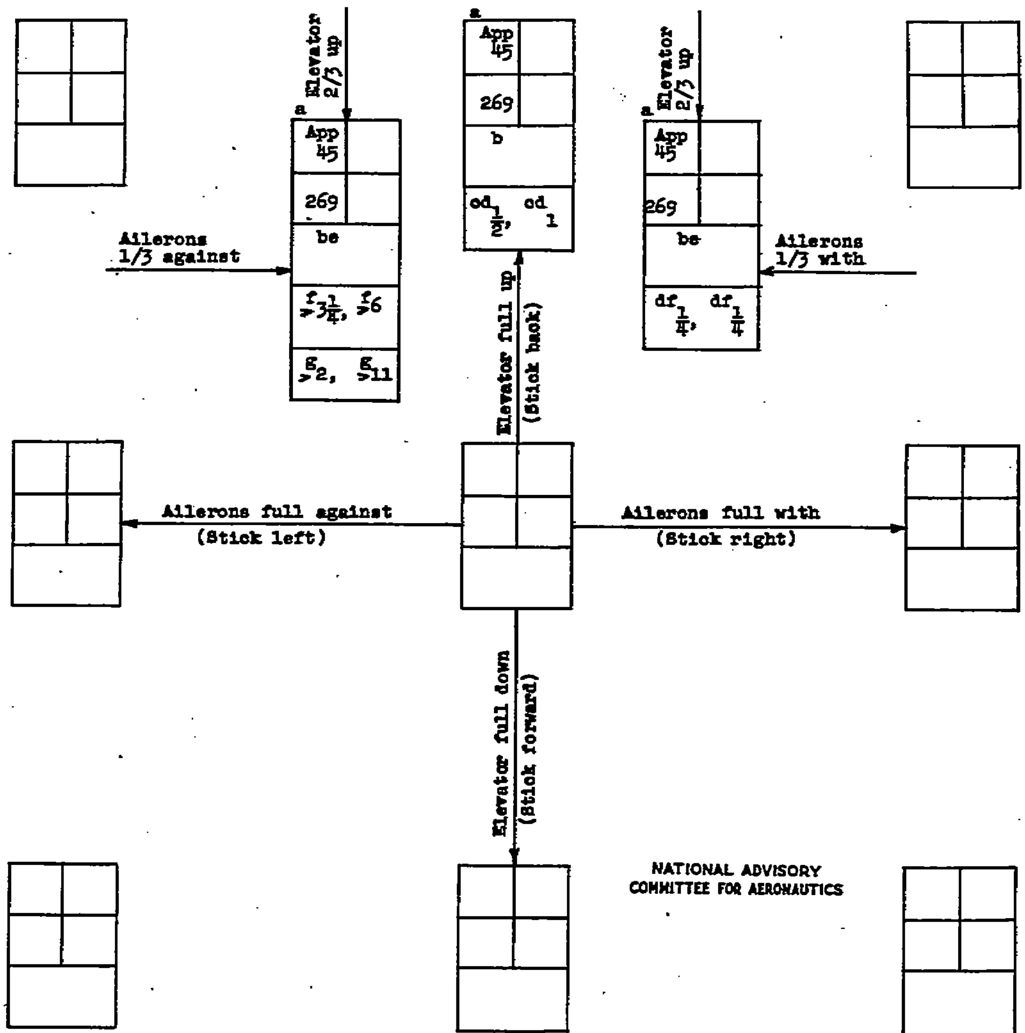
[a]Oscillatory spin. Average value or range of values given.
[b]Spinning rotation stopped in 2-1/2 turns or less after reversing rudder to against the spin. Model then glided across tunnel at a stalled attitude.
[c]Recovery attempted by simultaneously reversing the rudder from full with to full against the spin and the elevator from full up to 1/3 down.
[d]Model recovered in a steep dive.
[e]Visual estimate.
[f]Recovery attempted by simultaneously reversing the rudder from full with to full against the spin and the elevator from full up to 2/3 down.
[g]Recovery attempted by simultaneously reversing the rudder from full with to full against the spin and the elevator from full up to full down.
[h]Recovery attempted by reversing the rudder from full with to 2/3 against the spin.
[i]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.
[j]Recovery attempted by simultaneously reversing the rudder from full with to 2/3 against the spin and the elevator from 2/3 up to 2/3 down.
[k]Model goes inverted after recovery.

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 $\frac{1}{35}$-SCALE MODEL OF THE DOUGLAS XB-43 AIRPLANE IN GROSS WEIGHT CONDITION CASE IV WITH WING FUEL EXPENDED

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



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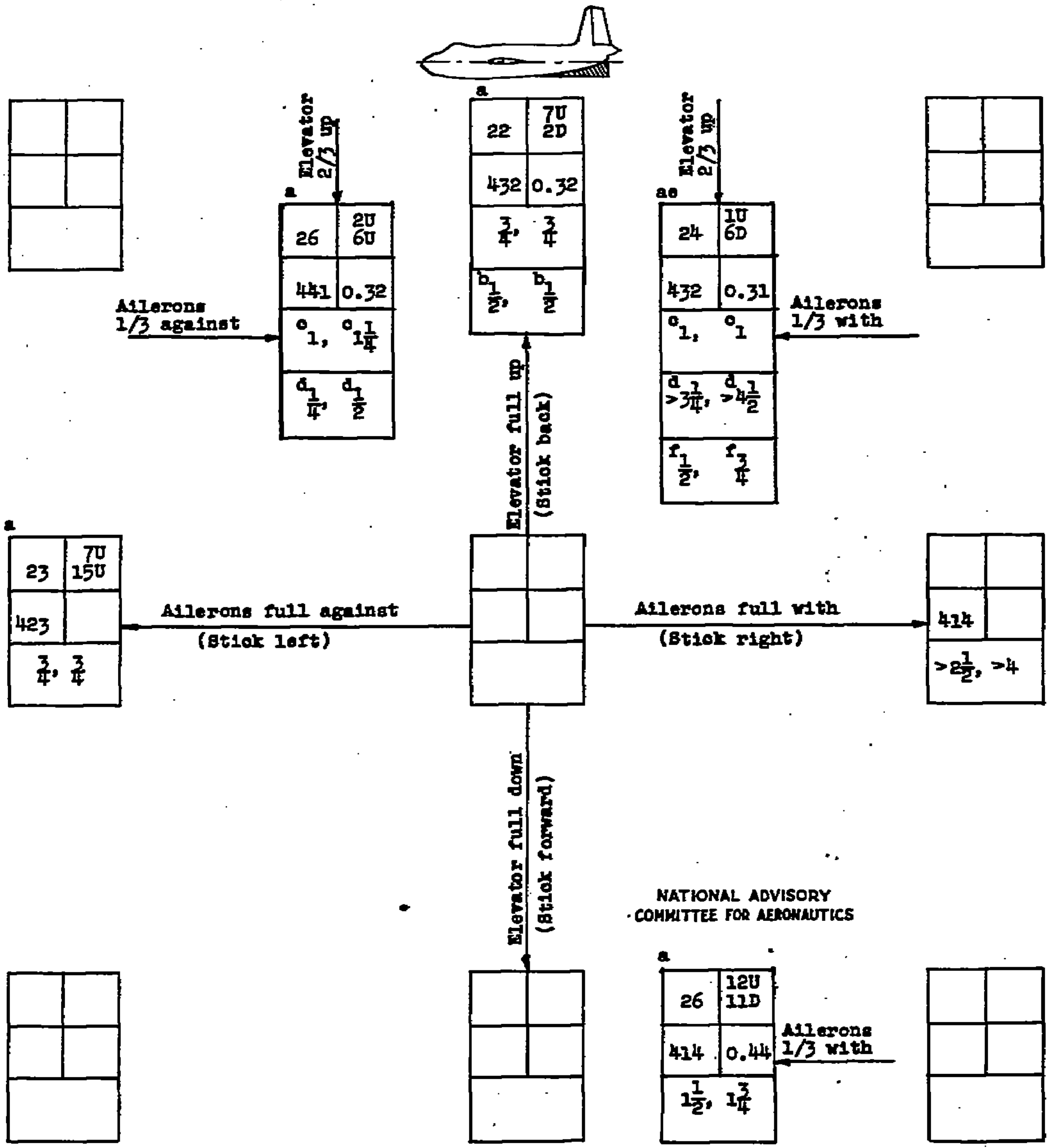
[a]Large radius spin with low rate of rotation.
[b]Spinning rotation stopped in one turn or less after reversing rudder to against the spin. Model then glided across tunnel at a stalled attitude.
[c]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from full up to 1/3 down.
[d]Model recovered in a steep dive.
[e]Recovery attempted by reversing the rudder from full with the spin to 2/3 against the spin.
[f]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.
[g]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from 2/3 up to full 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	

CHART 5.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{35}$-SCALE MODEL OF THE DOUGLAS XB-43 AIRPLANE IN GROSS WEIGHT CONDITION CASE I WITH WING FUEL EXPENDED AND VENTRAL FIN INSTALLED

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



[a]Oscillatory spin. Average value or range of values given.
[b]Recovery attempted by simultaneously reversing the rudder from full with the spin to full against the spin and elevator from full up to 1/3 down.
[c]Recovery attempted by reversing the rudder from full with the spin to 2/3 against the spin.
[d]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.
[e]Model wanders.
[f]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from 2/3 up to full 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	

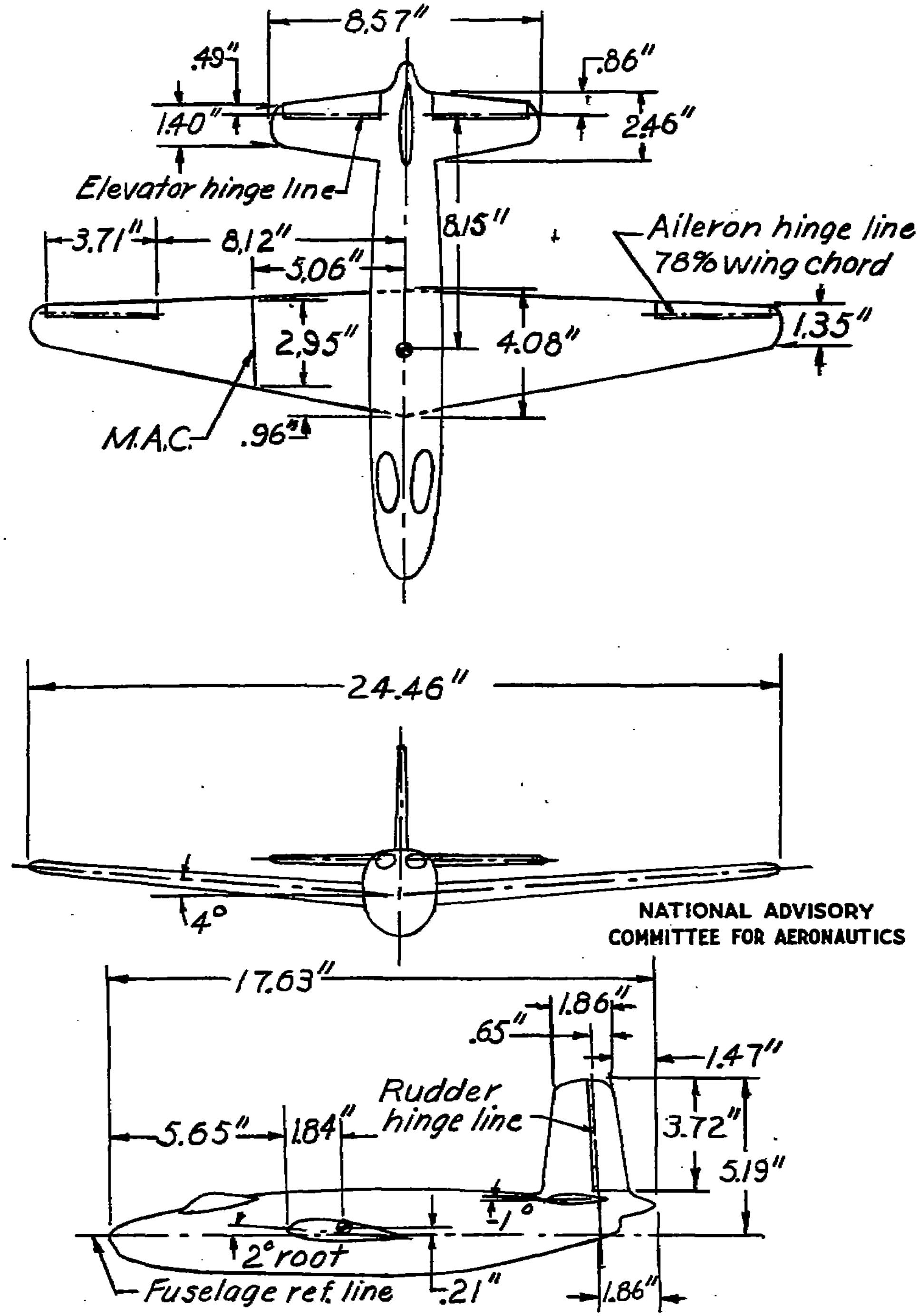


Figure 1.-Drawing of the $\frac{1}{35}$-scale model of the Douglas XB-43 airplane. Center-of-gravity position shown is for gross weight condition Case I.

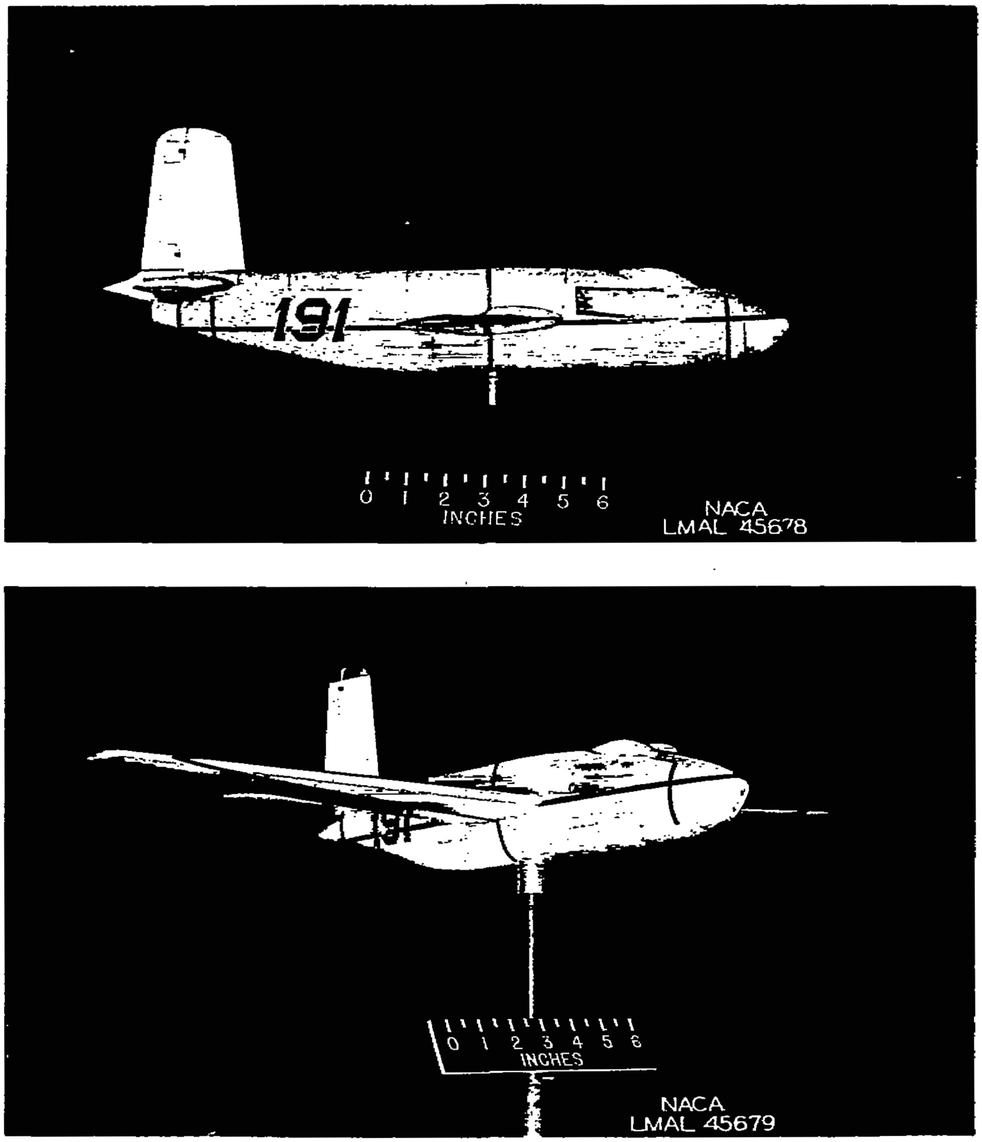


Figure 2.- The $\frac{1}{35}$-scale model of the Douglas XB-43 airplane as tested in the 20-foot free-spinning tunnel.

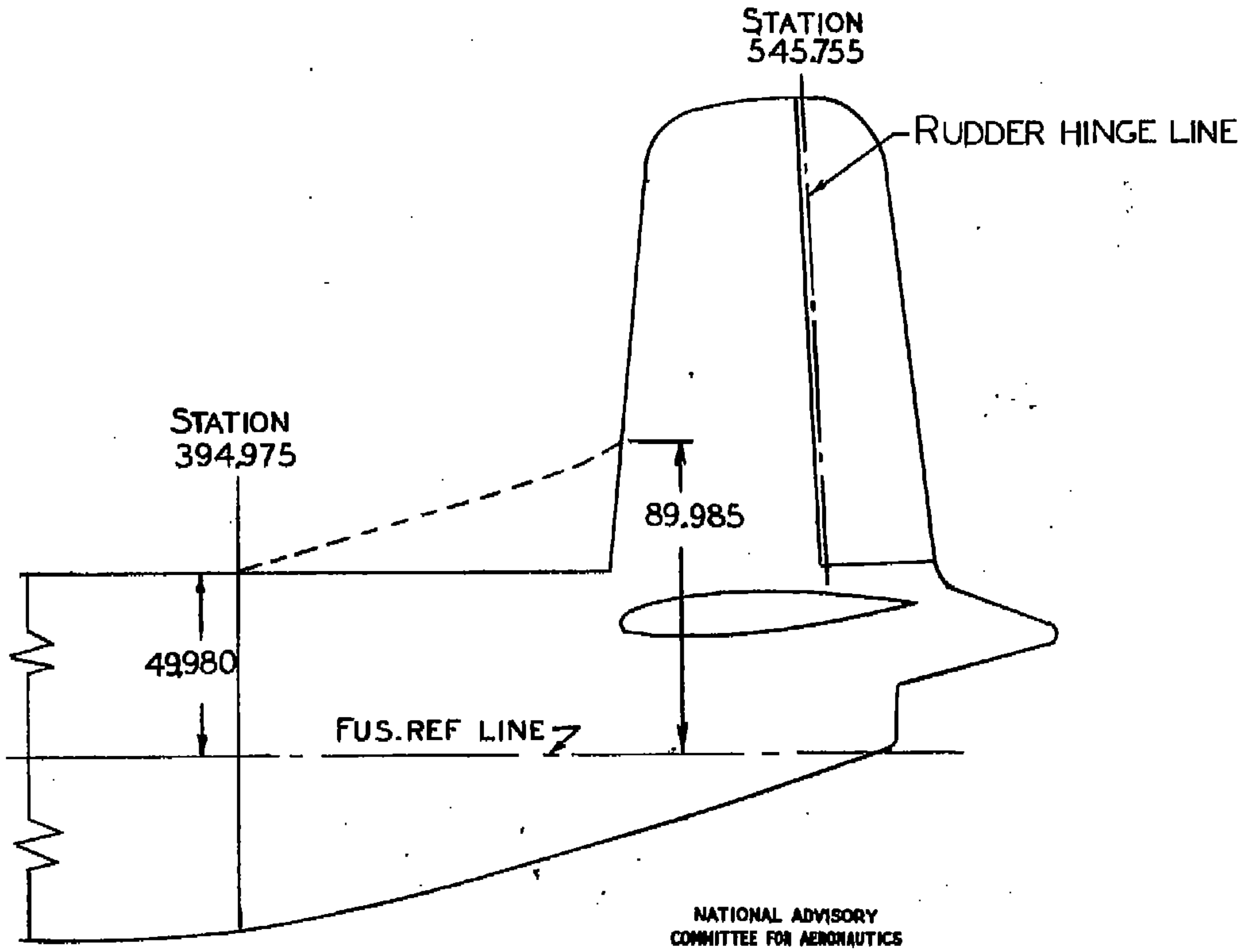


FIGURE 3.- DORSAL FIN (FALSE FIN) DESIGNED BY DOUGLAS AND TESTED ON THE $\frac{1}{35}$-SCALE MODEL OF THE DOUGLAS XB-43 AIRPLANE. DIMENSIONS ARE FULL-SCALE.

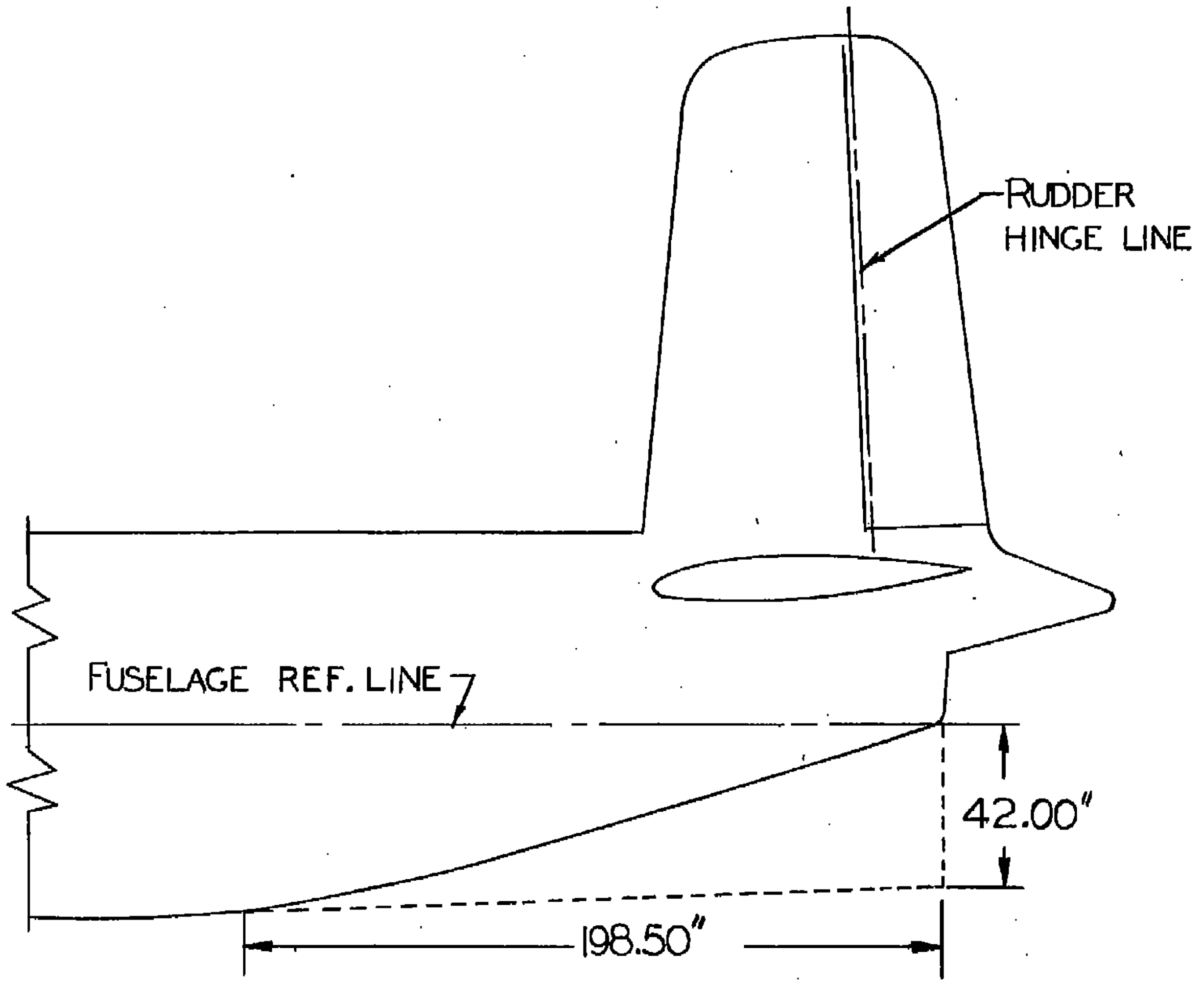


FIGURE 4.- VENTRAL FIN TESTED ON THE $\frac{1}{35}$-SCALE MODEL OF THE DOUGLAS XB-43 AIRPLANE. DIMENSIONS ARE FULL-SCALE.

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Figure 5.- Photograph of the $\frac{1}{35}$-scale model of the Douglas XB-43 airplane spinning in the Langley 20-foot free-spinning tunnel.

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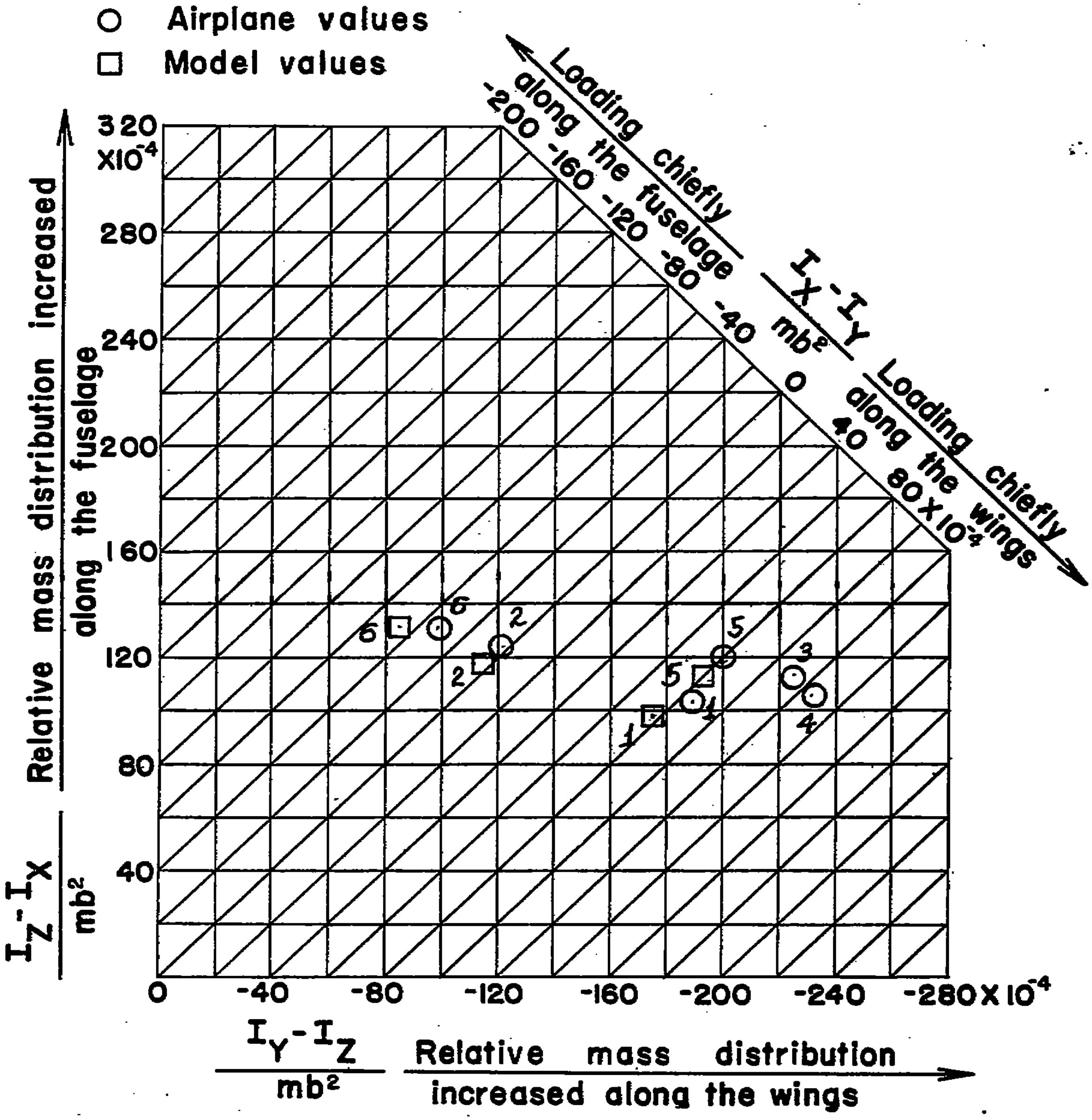

FIGURE 6. INERTIA PARAMETERS FOR VARIOUS LOADINGS POSSIBLE ON THE DOUGLAS XB-43 AIRPLANE AND FOR THE LOADINGS TESTED ON THE 1/35-SCALE MODEL (POINTS ARE FOR LOADINGS LISTED ON TABLE III).

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