REC'D MAR 26 1947

Revised Report

CLASSIFICATION CANCELLED

[redacted] RESTRICTED

RM No. L6L10

RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

INVESTIGATIONS OF TUMBLING CHARACTERISTICS OF A 1/20-SCALE MODEL OF THE NORTHROP N-9M AIRPLANE

By

George F. MacDougall, Jr.

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

JAN 27 1947

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

INVESTIGATIONS OF TUMBLING CHARACTERISTICS OF A 1/20-SCALE MODEL OF THE NORTHROP N-9M AIRPLANE

By George F. MacDougall, Jr.

SUMMARY

The tumbling characteristics of a 1/20-scale model of the Northrop N-9M airplane have been determined in the Langley 20-foot free-spinning tunnel for various configurations and loading conditions of the model. The investigation included tests to determine whether recovery from a tumble could be effected by the use of parachutes. An estimation of the forces due to acceleration acting on the pilot during a tumble was made. The tests were performed at an equivalent test altitude of 15,000 feet.

The results of the model tests indicate that if the airplane is stalled with its nose up and near the vertical, or if an appreciable amount of pitching rotation is imparted to the airplane as through the action of a strong gust, the airplane will either tumble or oscillate in pitch through a range of angles of the order of ±120°. The normal flying controls will probably be ineffective in preventing or in terminating the tumbling motion. The results of the model tests indicate that deflection of the landing flaps full down immediately upon the initiation of pitching rotation will tend to prevent the development of a state of tumbling equilibrium. The simultaneous opening of two 7-foot diameter parachutes having drag coefficients of 0.7, one parachute attached to the rear portion of each wing tip with a towline between 10 and 30 feet long, will provide recovery from a tumble. The accelerations acting on the pilot during a tumble will be dangerous.

INTRODUCTION

At 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 and the tumbling (a continuous rotation about the lateral axis of the airplane) characteristics of a 1/20-scale model of the Northrop N-9M airplane. The results of the spin-recovery tests have been presented in reference 1, and the results of the tumbling tests are presented herein.

The airplane represented by the model is a twin-engine, flying-wing airplane equipped with pusher propellers. The airplane was constructed and flown to provide data for use in the development of the Northrop XB-35 airplane and was approximately one-third the size of the XB-35. Directional control on the N-9M airplane is obtained by wing tip control surfaces designated by Northrop Aircraft, Inc. as "scoop rudders" and "pitch flaps." The scoop rudders are installed on the lower surface of the wing just forward of the leading edge of the pitch flaps. The pitch flaps are trailing-edge flaps and are deflected up when the scoop rudders move down. The pitch flaps are also used as a longitudinal trim device when the landing flaps are deflected. Longitudinal and lateral control are obtained with trailing-edge flaps designated by Northrop Aircraft, Inc. as "elevons." The elevons serve as both elevators and ailerons and are located just inboard of the directional control devices. Landing flaps are installed along the trailing edge of the wing between the plane of symmetry and the inboard end of the elevons.

The tumbling characteristics of the model were investigated for a basic loading designated by Northrop Aircraft, Inc. as flight test condition number one and also with the center of gravity moved forward. Tests were performed to determine the individual effects of deflecting the landing flaps, of extending the landing gear, and of deflecting the pitch flaps. The fin effect of windmilling propellers was ascertained from tests with horizontal and vertical equivalent propeller fin area installed. At the request of Northrop Aircraft, Inc., tests were performed with 20-percent and with 35-percent span auxiliary leading-edge slats installed and also with XB-35 type split rudders installed on each wing tip and opened simultaneously to determine the effect of these design modifications on the tumbling characteristics of the model. The effect of installing various amounts of horizontal area on a boom rearward of the model was investigated and tests were performed to determine whether recovery from a tumble could be effected by the use of parachutes. Approximate calculations were made of the forces that would be acting on the pilot's head when the airplane is tumbling.

SYMBOLS

b wing span, feet

S wing area, square feet

c wing chord at any station along the span

$\bar{c}$ mean aerodynamic chord, feet

$x/\bar{c}$ ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord

$z/\bar{c}$ ratio of distance between center of gravity and root chord line to mean aerodynamic chord (positive when center of gravity is below root chord line)

m mass of airplane, slugs

I_X, I_Y, I_Z moments of inertia about X, Y, and Z body axes, respectively, slug-feet^2

R distance from axis of tumbling rotation to pilot's head, feet

q full-scale rate of pitching rotation during tumble, radians per second

g acceleration due to gravity, approximately 32.2 feet per second

ρ air density, slug per cubic foot

μ relative density of airplane, $m/\rho Sb$

APPARATUS AND METHODS

Models

The 1/20-scale model of the Northrop N-9M airplane previously used for the spin tests reported in reference 1 was also used for the tumbling tests. Because of difficulties encountered in performing the tumbling tests, a second model was constructed and prepared for testing by Langley to expedite the test program. Dimensional and mass characteristics of the airplane represented by the models are given in table I and a three-view drawing of the models as tested in the clean configuration (flaps neutral and landing gear retracted) is presented as figure 1. Figures 2 and 3 are photographs of one of the models in the clean and landing configurations, respectively. The models were ballasted as described in reference 1 to obtain dynamic similarity to the airplane at an altitude of 15,000 feet ($\rho = 0.001496$ slug per cubic foot). A remote-control mechanism was mounted in one of the models to open the parachutes for recovery tests. The parachutes used were of the flat circular type, made of silk, and had a drag coefficient of approximately 0.7 based on the surface area of the canopy when spread out flat. The auxilary leading-edge slats and equivalent propeller fin area used for the tumbling tests were the same as those used for the spin tests reported in reference 1 and are shown on figures 4 and 5, respectively. Tests were performed with horizontal areas equal to 2 percent (previously used for spin tests), 5 percent, and 10 percent of the wing area installed on a boom rearward of the model as shown on figure 6. The installation of the XB-35 type split rudders and a comparison of the XB-35 type rudder controls with the N-9M rudder controls are presented on figure 7.

Wind Tunnel and Testing Technique

The tumbling tests were performed in the Langley 20-foot free-spinning tunnel, the operation and design of which is generally similar to that of the 15-foot free-spinning tunnel as described in reference 2. Various methods of launching were employed in the tumbling tests. In order to determine whether the model would start tumbling of its own accord, the model was released without rotation either from an attitude in which the model was approximately horizontal, from an attitude in which the nose was approximately 70° below the horizontal, from an attitude in which the model was approximately vertical with the nose up or was impelled into the tunnel without rotation with the nose slightly above the horizontal.

In order to determine whether the model would stop tumbling once the tumbling motion had been started, the model was launched into the tunnel by hand with either positive or negative pitching rotation. The tumbling tests in which the model was released without rotation were arbitrarily performed at a constant tunnel airspeed of approximatly 75 feet per second and those in which the model was launched with rotation were arbitrarily performed at a constant airspeed of approximately 65 feet per second. The initial pitching rotation imparted to the model for the tests in which it was launched with rotation was sufficient to tumble the model through one to three complete revolutions. For the cases in which the model would tumble, it could make only five to six complete tumbles before traveling across the tunnel and hitting the safety net on the opposite side.

Motion pictures were taken of the tests so that a study could be made of the motion of the model during the tumble and, for those cases for which the model would not tumble, of the motion after launching. An approximation of the vertical rate of descent of the model during a tumble was determined from film records of the tests and from the tunnel airspeed. The camera speed being known, the apparent vertical rate of descent was determined from the number of frames of film in which the model moved a certain vertical distance in the tunnel. This apparent vertical rate of descent was added to the tunnel airspeed to give an approximation of the vertical rate of descent of the model during the tumble. An approximation of the horizontal component of velocity during a tumble was obtained from the film records in a manner similar to that for the vertical component.

The model was launched into the tunnel with initial positive pitching rotation for the tests made to determine whether recovery from a tumble could be effected by the use of parachutes. The parachutes were opened for recovery approximately two complete tumbles after the model was launched. For some of the tests, parachutes installed on both wing tips were opened simultaneously whereas for other tests only the parachute on one wing tip was opened. The parachutes were installed on the model as described in reference 1 for the spin tests. The points of attachment for the parachute towlines are shown in figure 8.

PRECISION

The measurement of the rate of rotation and of the vertical and horizontal velocity components of the path of the model while tumbling are believed to be accurate within limits of ±5 percent and ±10 percent, respectively.

The accuracy of the ballasting of the models for the tumbling tests was the same as that reported in reference 1 for the spin tests. The controls were set with an accuracy of ±1°.

TEST CONDITIONS

The conditions tested in the investigation to determine the tumbling characteristics of the models are listed in table II. Full-scale values of mass parameters for the loadings tested on the models and for various loading conditions of the airplane are given in table III. As previously mentioned, the basic test condition was designated as flight test condition number one, and in addition, tests were made with the center of gravity moved forward 5 percent of the mean aerodynamic chord. For each test condition, various elevon positions including neutral and maximum deflections for longitudinal and lateral control were investigated.

The N-9M airplane is equipped with a wheel mounted on top of a stick to move the elevons for longitudinal and lateral control. Longitudinal movement of the stick and wheel moves both elevons either up or down together for longitudinal control whereas turning the wheel moves one elevon up and the other elevon down for lateral control. Although there was no stick or wheel in the models, control deflections are generally referred to herein in terms of stick and wheel positions. The elevon deflections were the same as those given in reference 1 for the spin tests and are presented on figure 9. The scoop rudders were maintained at neutral throughout the entire test program. The pitch flaps were neutral except when the model was in the landing configuration and for a few tests in which both pitch flaps were set 26° up in order to determine the effect of pitch flap deflection on the tumbling characteristics of the model. The pitch flaps were removed from both wing tips and XB-35 type split rudders were installed for tests to determine whether this type of rudder control, acting in a manner similar to that of dive brakes, would have an effect on the tumbling characteristics of the model. The split rudders on each wing tip were open simultaneously ±60° for these tests. Unless otherwise specifically stated in the discussion, the model was in the clean configuration and ballasted to represent flight test condition number one.

RESULTS AND DISCUSSION

As previously mentioned, for convenience, two models of the N-9M airplane were used in the tumbling investigation. The results of preliminary tests indicated that both models had similar tumbling characteristics. The results are presented herein therefore without regard to the particular model used.

Interpretation of Results

Inasmuch as no data on the tumbling of full-scale aircraft are available, the accuracy of predicting airplane tumbling characteristics from model data is unknown. In applying the model results to the full-scale airplane the following interpretation has been placed on the results from different methods of launching the model.

When launched into the tunnel, either with or without initial pitching rotation, the model either would or would not tumble. If the model tumbled with either method of launching it was taken as an indication that the corresponding airplane could tumble, although the airplane probably would be more likely to tumble if the model started tumbling when launched with no pitching rotation. If the model stopped tumbling after being launched with initial pitching rotation, the results were interpreted to mean that the corresponding airplane would not tumble.

Clean Configuration

Flight test condition number one.- In general, the model continued to tumble when launched with either initial negative or positive pitching rotation regardless of elevon deflection (table IV-A) thereby indicating that elevon deflection had no appreciable effect on the tumbling characteristics of the model. For a typical tumble, the vertical component of velocity was approximately 150 feet per second, full scale, the horizontal component of velocity was approximately 75 feet per second, full scale, and the rate of rotation was approximately 1 rps, full scale. The components of velocity and the rate of rotation were obtained from the film records as previously described and are shown graphically on figure 10.

When released from a nose-up vertical attitude (table V-A), the model sometimes started to tumble and at other times oscillated in pitch through a range of approximately $\pm 120^{\circ}$ measured from the nose-down position. These oscillations appeared to be only lightly damped before the model reached the safety net at the bottom of the tunnel. Figures 11 and 12 are reproductions of motion-picture records of a typical tumble and of a typical oscillatory motion, respectively, when the model was released from a vertical attitude with its nose up. It appears from the results of these tests that the airplane may start to tumble if it is stalled with its nose up near the vertical or if it is forced into a nose-up attitude by a strong gust.

The model dived into the safety net with oscillations in pitch of the order of ±15° when released from an attitude with its nose approximately 70° below the horizontal (table VI-A). When the model was released from a horizontal attitude (table VI-B), it made one or two oscillations in pitch of approximately ±40° and then dived with the oscillations rapidly diminishing in amplitude. The motion of the model when impelled into the tunnel with the nose of the model slightly above the horizontal (table VII) was generally similar to that when it was released from a horizontal attitude. From the results of the tests with these latter three types of launchings, it appears that the airplane will not start tumbling when it is stalled with its nose slightly above the horizontal or when it is in a dive.

Inasmuch as the model did not start tumbling for the clean configuration, flight test condition number one, as previously mentioned, when it was released from a horizontal attitude, when it was released with its nose 70° below the horizontal, or when it was impelled into the tunnel with its nose slightly above the horizontal, it was believed that the model also would not tumble for any of the remaining configurations and loadings on the test program when it was launched in any of these three manners. These methods of launching, therefore, were not employed for the remainder of the test program.

Equivalent fin effect of propellers.- The results of the tests with propellers simulated which are presented on tables IV-B and V-B were generally similar to those obtained without the propeller fin area and thereby indicate that the fin effect of the propellers was not sufficiently large to appreciably effect the tumbling characteristics of the model.

Center of gravity forward.- The results presented on tables IV-C and V-C indicate that movement of the center of gravity 5 percent of the mean aerodynamic chord forward of normal had a somewhat beneficial effect on the tumbling characteristics of the model. When launched with initial negative pitching rotation (nose down), the model usually stopped tumbling and made two oscillations in pitch of approximately ±120° after which the oscillations started to damp out. No appreciable effect of center-of-gravity location was noticed, however, when the model was launched with initial positive pitching rotation. When released from a vertical attitude with its nose up, the model oscillated in a manner generally similar to that previously described for launchings with initial negative pitching moment. It is believed that the decreased tendency of the model to tumble with the center of gravity forward can be attributed to the increase in longitudinal stability associated with the forward movement of the center of gravity.

Auxiliary Slats Installed

Installation of 20-percent span auxiliary leading-edge slats had little effect on the tumbling characteristics when the model was launched with initial pitching rotation. (See table IV-D.) When the model was released at a vertical attitude with its nose up, however, the tendency of the model to start tumbling was diminished and the amplitude of the oscillations in pitch was decreased. (See table V-D.) Installation of 35-percent span auxiliary leading-edge slats had a somewhat beneficial effect on the tumbling characteristics of the model in that the model would not now continue tumbling after being launched with initial negative pitching rotation when the stick was back. (See table IV-E.) There was also a reduced tendency for the model to continue tumbling when the stick was forward for launchings with either initial negative or positive pitching rotation. The results on table V-E also show that for launchings from a nose-up vertical attitude, the model exhibited less tendency to tumble, and the oscillations in pitch damped out more rapidly when the 35-percent span slats were installed than when the model was in the original configuration.

XB-35 Type Split Rudders Installed

The results on table IV-F show that installation of the XB-35 type split rudders had no appreciable effect on the tumbling characteristics of the model when launched with initial pitching rotation. A somewhat favorable effect of installing the split rudders was noticed when the model was released from a vertical attitude with its nose up in that the model generally would not now tumble. (See table V-F.)

Landing Configuration

The results obtained with the model in the landing configuration (landing gear extended, landing flaps 50° down, and pitch flaps 26° up) were generally similar to those for the clean configuration when the model was launched with either positive or negative initial pitching rotation. (See table IV-G.) A favorable effect of the landing configuration was observed, however, when the model was released from a nose-up vertical attitude. For this latter type of launching, the model made one or two oscillations in pitch of the order of $\pm 120^\circ$ after which the oscillations damped out and the model then dived to the safety net. (See table V-G.)

Tests were next performed to ascertain the contribution of the landing flaps, the landing gear, and the pitch flaps in preventing the model from tumbling, and in reducing the amplitude of the oscillations in pitch, when released from a nose-up attitude in the landing configuration. The results of these tests are presented on table V-H through V-K and indicate that the deflection of the landing flaps was the main factor in preventing the establishment of a state of tumbling equilibrium and of reducing the amplitude of the oscillations in pitch when the model was in the landing configuration.

Horizontal Area Installed Rearward of the Model

Installation of horizontal area rearward of the model had a beneficial effect on the tumbling characteristics of the model. When launched with either initial positive or negative pitching rotation with horizontal area equal to either 10 percent or to 5 percent of the wing area installed on a boom rearward of the model, the model stopped tumbling, made two or three oscillations in pitch of rapidly diminishing amplitude, and then dived to the safety net for all stick - wheel positions. (See table IV-H and IV-I.) Installation of horizontal area equal to 2 percent of the wing area, however, had no appreciable effect on the tumbling characteristics of the model when the model was launched with initial pitching rotation. (See table IV-J.)

The model would not start tumbling when released from a nose-up vertical attitude when any one of the three previously mentioned horizontal areas were installed. (See table V-L, V-M, and V-N.) After release from the nose-up attitude, the model made two or three oscillations in pitch of diminishing amplitude and then dived down into the safety net. The reduced tendency of the model to tumble and to oscillate in pitch with horizontal area installed may be explained on the basis of an increase in longitudinal stability contributed by the horizontal area.

Parachutes

The results of the tests performed to determine whether the tumbling rotation could be stopped by opening parachutes are presented on table VIII. It was found that when parachutes attached to the fixed portion of the wing between the pitch flaps and the elevons were opened, the towlines and parachutes wrapped around the wing and the model continued tumbling. Inasmuch as both relatively short (2.5 feet full scale) and relatively long (30.0 feet full scale) towlines were tested, the results indicate that parachutes will probably be entirely ineffective in stopping the tumbling rotation regardless of towline length when the towlines are attached inboard of the extreme wing tips. When a 7-foot full-scale parachute was attached to each wing at the extreme tip with either a 10- or a 30-foot full-scale towline, the model stopped tumbling in one to one and one-half rotations after simultaneous opening of both parachutes. After the tumbling rotation stopped, the model oscillated in pitch approximately $\pm 90^\circ$ measured from the nose-down position until striking the safety net. Inasmuch as it was previously indicated that the model stopped oscillating and then dived when it was released from a horizontal attitude, it appears that the oscillations in pitch obtained after the parachutes stopped the tumbling rotation on the model can be eliminated on the airplane by releasing the parachutes after the tumbling rotation has definitely been stopped. A motion-picture record of a typical recovery from a tumble by the use of parachutes attached to the wing tips is reproduced as figure 13. The model sometimes stopped tumbling and sometimes continued tumbling when only the parachute attached to one wing tip was opened for recovery. It appears, therefore, that in order to assure cessation of the tumbling rotation by the use of parachutes, parachutes on both wing tips should be opened simultaneously.

Prevention and Termination of Tumbling

The results presented herein show that the normal flying controls of the Northrop N-9M airplane will probably be ineffective in preventing or in terminating the tumbling rotation. It has been indicated, however, that deflection of the landing flaps full down before the tumbling rotation has been established may prevent the development of a stable tumbling condition.

The results presented herein have also shown that the airplane probably will not start tumbling unless it is stalled at a nearly vertical attitude with its nose up or is forced into a tumble, as by a strong gust. It is recommended therefore that care be exercised when maneuvering to avoid stalling the airplane with its nose up near the vertical. If the airplane is to be flown through maneuvers in which the nose becomes nearly vertical, it is recommended that parachutes be installed for emergency recovery from a tumble. A satisfactory parachute installation for recovery from a tumble consists of a parachute at least 7 feet in diameter mounted either inside the structure with provisions for positive ojection or on the upper surface of each wing tip. The parachutes should be attached to the rear portion of the rospectivo wing tip with a towline between 10 and 30 feet long and should be opened simultaneously for recovery if the airplane starts to tumble.

If the airplane is inadvertently stalled with its nose up and near the vertical, the landing flaps should immediately be deflected full down as rapidly as possible in an attempt to prevent the establishment of a stable tumbling condition. If the landing flaps are deflected full down before the airplane has fallen off appreciably from the stall, the airplane will not tumble but will make a few oscillations in pitch on the order of $\pm 120^{\circ}$ after which the oscillations will damp out. The stick should be moved in a direction such as to counteract the pitching motion in order to decrease the time required for the oscillations to damp out.

Accelerations in a Tumble

Approximate calculations were made to determine the accelerations acting on the pilot's head during a typical tumble for flight test condition number one. The accelerations were considered to be caused only by the rotation about the lateral axis, the effect of the vertical and horizontal motions being neglected. The axis of tumbling rotation was assumed to be at the center of gravity making the radius from the axis of tumbling rotation to the pilot's head approximately 3.5 feet. The full-scale rate of rotation was approximately 6.3 radians per second. When only the acceleration due to rotation (q^2R) is considered, it appears that an acceleration of approximately 4.3g would be acting on the pilot's head during a typical tumble. Reference 3 indicates that positive accelerations (such as to push the pilot down in the seat) of 5g will probably cause temporary loss of vision and that forces of 6 to 7g will cause loss of consciousness. It is further pointed out in reference 3 that negative accelerations of three times the pull of gravity will cause symptoms of concussion of the brain and that negative accelerations of 5g may result in massive cerebral hemorrages and death. It thus appears that if the airplane tumbles, the pilot may be in acute physical danger as a result of the accelerations created by the tumbling rotation, especially if the airplane tumbles in a direction such as to cause negative accelerations to act on his body and head.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of the results of the tumbling tests of a 1/20-scale model of the Northrop N-9M airplane, the following conclusions and recommendations regarding the tumbling characteristics of the airplane at an altitude of 15,000 feet are made.

1. If the airplane is stalled with its nose up and near the vertical or if an appreciable pitching rotation is imparted to the airplane as by a gust when it is in the clean configuration for flight test condition number one, it will either start tumbling or will oscillate in pitch through a range of angles of the order of $\pm 120^{\circ}$ from the nose-down position. The normal flying controls will probably be ineffective either in preventing the tumble or in producing recovery once a tumble has started.

2. Immediate deflection of the landing flaps full down when the airplane is stalled with its nose up near the vertical will prevent the airplane from tumbling and will reduce the tendency of the airplane to oscillate in pitch after nosing down from the stall.

3. Simultaneously opening two parachutes 7 feet in diameter and having a drag coefficient of 0.7, one parachute attached to the rear portion of each wing tip, will effect recovery from a tumble.

4. Installation of a horizontal tail of the order of 5 percent of the wing area rearward of the airplane will prevent the airplane from tumbling.

5. The tendency of the airplane to tumble and to oscillate in pitch will not be as great when the center of gravity is forward approximately 5 percent of the mean aerodynamic chord as when the center of gravity is in its normal location for flight test condition number one. The tendency of the airplane to tumble will also be reduced when leading-edge slats are installed.

6. The accelerations acting at the pilot's head during a tumble will be dangerous, especially when acting in a negative direction.

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

George F. MacDougall Jr.
George F. MacDougall, Jr.
Aeronautical Engineer

Approved:

Hartley A. Soulé
Hartley A. Soulé
Chief of Stability Research Division

CGB

REFERENCES

1. MacDougall, George F., Jr. and Lichtenstein, Jacob H.: Free-Spinning-Tunnel Tests of a 1/20-Scale Model of the Northrop N-9M Airplane. NACA RM No. L6G30, Army Air Forces, 1946.

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

3. Armstrong, Harry G. and Heim, J. W.: The Effect of Acceleration on the Living Organism. ACTR No. 4362, Materiel Div., Army Air Corps, Dec. 1, 1937.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE

NORTHROP N-9M AIRPLANE

Length over all, ft	17.78
Propellers, type	Pusher
Propellers, diameter, ft	7.00
Propellers, number	2
Propellers, blades on each	2
Wing:	
Span, ft	60.00
Area, sq ft	490.0
Section, root	NACA-65,3-019
Section, tip	NACA-65,3-018
Twist, tip leading edge down, deg	4.0
Dihedral, 25 percent chord line, deg	2.0
Aspect ratio	7.4
Taper ratio	4.0
Sweepback, 25 percent chord line, deg	21.9
Mean aerodynamic chord, in.	109.8
Leading edge of mean aerodynamic chord rearward of leading edge of root chord, in.	69.7
Elevons:	
Chord rearward of hinge line, ft	1.57
Span, percent of wing span	33.6
Area rearward of hinge line, percent of wing area	6.5
Pitch flaps:	
Chord, percent of wing chord	24.2
Span, percent of wing span	23.6
Area rearward of hinge line, percent of wing area	3.1
Scoop rudders:	
Span, percent of wing span	21.5
Landing flaps:	
Span, percent of wing span	35.3
Total area, percent of wing area	10.1

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE II.- CONDITIONS TESTED IN THE INVESTIGATION OF THE TUMBLING CHARACTERISTICS OF THE 1/20-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE

CONFIDENTIAL

No.	Change from original, clean configuration	Loading	Type of launching	Landing flaps	Pitch flaps (deg)	Landing gear	Slots	Horizontal area	Split rudders	Parachute attached	Data presented on table
1	None	Flight test condition number 1	With initial pitching rotation	Neutral	0	Retracted	None	None	None	None	IV-A
2	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	0	----do---	-do-	----do----	---do----	---do----	V-A
3	---------do---------	--------do---------	Released with nose approximately 70° below horizontal	---do--	0	----do---	-do-	----do----	---do----	---do----	VI-A
4	---------do---------	--------do---------	Released from horizontal attitude	---do--	0	----do---	-do-	----do----	--do----	---do----	VI-B
5	---------do---------	--------do---------	Impelled into tunnel with nose slightly above horizontal	---do--	0	----do---	-do-	----do----	--do----	---do----	VII
6	Equivalent propeller fin area installed	--------do---------	With initial pitching rotation	---do--	0	----do---	-do-	----do----	---do----	---do----	IV-B
7	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	0	----do---	-do-	----do----	---do----	---do----	V-B
8	None	Center of gravity 5 percent $\bar{c}$ forward of normal location for flight test condition number 1	With initial pitching rotation	---do--	0	----do---	-do-	----do----	---do----	---do----	IV-C
9	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	0	----do--	-do--	----do----	---do----	---do----	V-C
10	20-percent span auxiliary leading-edge slats installed	Flight test condition number 1	With initial pitching rotation	---do--	0	----do--	Open	----do----	---do----	---do----	IV-D
11	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	0	----do---	-do--	----do----	---do----	---do----	V-D
12	35-percent span auxiliary leading-edge slats installed	--------do---------	With initial pitching rotation	---do--	0	----do---	-do--	----do----	---do----	---do----	IV-E
13	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	0	----do---	-do--	----do----	---do----	---do----	V-E
14	XB-35 type split rudders installed	--------do---------	With initial pitching rotation	---do--	0	----do---	None	----do----	±60° on both wing tips	---do----	IV-F
15	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	0	----do---	-do--	----do----	±60° on both wing tips	---do----	V-F
16	Landing	--------do---------	With initial pitching rotation	50° down	26 up	Extended	-do--	----do----	None	---do----	IV-G
17	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	26 up	----do---	-do--	----do----	---do----	---do----	V-G
18	Landing flaps deflected and landing gear extended	--------do---------	------------do------------	---do--	0	----do---	-do--	----do----	---do----	---do----	V-H
19	Landing flaps deflected	--------do---------	------------do------------	---do--	0	Retracted	-do--	----do----	---do----	---do----	V-I
20	Landing gear extended	--------do---------	------------do------------	Neutral	0	Extended	-do--	----do----	---do----	---do----	V-J
21	Pitch flaps deflected	--------do---------	------------do------------	---do--	26 up	Retracted	-do--	----do----	---do----	---do----	V-K
22	Horizontal area installed	--------do---------	With initial pitching rotation	---do--	0	----do---	-do--	Equal to 10 percent of wing area	---do----	---do----	IV-H
23	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	0	----do---	-do--	----do----	---do----	---do----	V-L
24	---------do---------	--------do---------	With initial pitching rotation	---do--	0	----do---	-do--	Equal to 5 percent of wing area			IV-I
25	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	0	----do---	-do--	----do----	---do----	---do----	V-M
26	---------do---------	--------do---------	With initial pitching rotation	---do--	0	----do---	-do--	Equal to 2 percent of wing area	---do----	---do----	IV-J
27	---------do---------	--------do---------	Released from nose-up vertical attitude	---do--	0	----do---	-do--	----do----	---do----	---do----	V-N
28	Two parachutes installed	--------do---------	With initial pitching rotation	---do--	0	----do---	-do--	None	---do----	Between elevons and pitch flaps	VIII
29	---------do---------	--------do---------	------------do------------	---do--	0	----do---	-do--	----do----	---do----	At wing tip	VIII
30	One parachute installed	--------do---------	------------do------------	---do--	0	----do---	-do--	----do----	---do----	Between elevons and pitch flaps	VIII

CONFIDENTIAL

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE III.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR VARIOUS LOADINGS POSSIBLE ON THE NORTHROP N-9M AIRPLANE AND FOR THE LOADINGS TESTED ON THE 1/20-SCALE MODELS

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

CONFIDENTIAL

No.	Loading	Weight (lb)	μ		Center-of-gravity location		Moments of inertia about center of gravity		
			Sea level	15,000 feet	$\frac{X}{\bar{c}}$	$\frac{Z}{\bar{c}}$	I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)
				Airplane values					
1	Flight test condition number 1	6,517	2.90	4.61	0.29	-0.04	19,045	2,288	21,099
2	Flight test condition number 2	6,717	2.99	4.75	.27	-.04	19,058	2,574	21,373
3	Flight test condition number 3	6,917	3.08	4.89	.25	-.04	19,051	2,879	21,684
				Model values					
1	Flight test condition number 1	6,526	2.91	4.62	0.29	-0.04	19,138	2,274	21,298

CONFIDENTIAL

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE IV.- TUMBLING CHARACTERISTICS OF THE 1/20-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE

WHEN LAUNCHED WITH INITIAL PITCHING ROTATION

[Tunnel airspeed for all tests was approximately 65 feet per second]

CONFIDENTIAL

Change from original, clean configuration	Loading	Direction of initial pitching rotation	Stick position	Wheel position	Landing flaps	Pitch flaps (deg)	Landing gear	Behavior of model
A. Original model								
None	Flight test condition number 1	Positive	Full back	Full left	Neutral	0	Retracted	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling and oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	Full back	Full left	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling and oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling and oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
B. Effect of equivalent propeller fin area								
Equivalent propeller fin area installed	Flight test condition number 1	Positive	Full back	Full left	Neutral	0	Retracted	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	------do------	Full left	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
C. Effect of center-of-gravity location								
None	Center-of-gravity 5 percent $\bar{c}$ forward of normal location for flight test condition number 1	Positive	Full back	Full left	Neutral	0	Retracted	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	------do------	Full left	---do--	0	----do---	Stopped tumbling, made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling, made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Stopped tumbling, made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling, made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Stopped tumbling, made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.

CONFIDENTIAL

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE IV.- TUMBLING CHARACTERISTICS OF THE 1/20-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE - Continued

CONFIDENTIAL

Change from original, clean configuration	Loading	Direction of initial pitching rotation	Stick position	Wheel position	Landing flaps	Pitch flaps (deg)	Landing gear	Behavior of model
D. Effect of 20-percent span slots								
20-percent span, auxiliary leading-edge slats installed	Flight test condition number 1	Positive	Full back	Full left	Neutral	0	Retracted	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling, made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Continued tumbling.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	Full back	Full left	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Stopped tumbling, made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
E. Effect of 35-percent span slots								
35-percent span, auxiliary leading-edge slats installed	Flight test condition number 1	Positive	Full back	Full left	Neutral	0	Retracted	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Stopped tumbling, made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Continued tumbling.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling, made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	Full back	Full left	---do--	0	----do---	Stopped tumbling, made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling, made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Stopped tumbling, made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Stopped tumbling, made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling, made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.

CONFIDENTIAL

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE IV.- TUMBLING CHARACTERISTICS OF THE 1/20-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE - Concluded

Change from original, clean configuration	Loading	Direction of initial pitching rotation	Stick position	Wheel position	Landing flaps	Pitch flaps (deg)	Landing gear	Behavior of model
F. Effects of split rudders								
XB-35 type split rudders installed and deflected ±60° on both wing tips	Flight test condition number 1	Positive	Full back	Full left	Neutral	0	Retracted	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	------do------	Full left	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
G. Effect of landing configuration								
Landing	Flight test condition number 1	Positive	Full back	Full left	50° down	26° up	Extended	Continued tumbling.
Do----------	---------do----------	-----do-----	------do------	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	Full back	Full left	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	------do------	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
H. Effect of installing horizontal area equal to 10 percent of the wing area								
Horizontal area equal to 10 percent of the wing area installed on a boom rearward of the model	Flight test condition number 1	Positive	Full back	Full left	Neutral	0	Retracted	Stopped tumbling, oscillations in pitch damped out rapidly, then dived.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	Full back	Full left	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
I. Effect of installing horizontal area equal to 5 percent of the wing area								
Horizontal area equal to 5 percent of the wing area installed on a boom rearward of the model	Flight test condition number 1	Positive	Full back	Full left	Neutral	0	Retracted	Stopped tumbling, oscillations in pitch damped out rapidly, then dived.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	------do------	Full left	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
J. Effect of installing horizontal area equal to 2 percent of the wing area								
Horizontal area equal to 2 percent of the wing area installed on a boom rearward of the model	Flight test condition number 1	Positive	Full back	Full left	Neutral	0	Retracted	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling, made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Continued tumbling.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Negative	------do------	Full left	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Neutral	---do--	0	----do---	Sometimes continued tumbling; sometimes stopped tumbling, made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	-----do-----	Neutral	----do----	---do--	0	----do---	Continued tumbling.
Do----------	---------do----------	-----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	-----do-----	Full back	Full right	---do--	0	----do---	Do.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE V.- TUMBLING CHARACTERISTICS OF THE 1/20-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE WHEN RELEASED WITHOUT ROTATION FROM A NOSE-UP VERTICAL ATTITUDE

[Tunnel airspeed for all tests was approximately 75 feet per second full scale]

CONFIDENTIAL

Change from original, clean configuration	Loading	Stick position	Wheel position	Landing flaps	Pitch flaps (deg)	Landing gear	Behavior of model
A. Original model							
None	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Sometimes tumbled; sometimes oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.
B. Effect of equivalent propeller fin area							
Equivalent propeller fin area installed	Flight test condition number 1	Full forward	Full left	Neutral	0	Retracted	Oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Sometimes tumbled; sometimes oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.
C. Effect of center-of-gravity location							
None	Center of gravity 5 percent $\bar{c}$ forward of normal location for flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
D. Effect of 20-percent span slots							
20-percent span auxiliary leading-edge slats installed	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Sometimes tumbled; sometimes made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Made two oscillations in pitch of approximately ±120° measured from the nose-down position, then oscillations started to damp out.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.

CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE V.- TUMBLING CHARACTERISTICS OF THE 1/20-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE - Continued

Change from original, clean configuration	Loading	Stick position	Wheel position	Landing flaps	Pitch flaps (deg)	Landing gear	Behavior of model
E. Effect of 35-percent span slots							
35-percent span auxiliary leading-edge slats installed	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Sometimes tumbled; sometimes made one or two oscillations in pitch of approximately ±120° measured from the nose down position, oscillations started to damp out, then dived.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
F. Effect of split rudders							
XB-35 type split rudders installed and deflected ±60° on both wing tips	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Sometimes tumbled; sometimes oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Sometimes tumbled; sometimes oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
G. Effect of landing configuration							
Landing	Flight test condition number 1	Full back	Full left	50° down	26 up	Extended	Made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
H. Effect of landing flaps and landing gear							
Landing flaps deflected and landing gear extended	Flight test condition number 1	Full back	Neutral	50° down	0	Extended	Made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.

TABLE V.- TUMBLING CHARACTERISTICS OF THE 1/20-SCALE MODELS OR THE NORTHROP N-9M AIRPLANE - Concluded

CONFIDENTIAL

Change from original, clean configuration	Loading	Stick position	Wheel position	Landing flaps	Pitch flaps (deg)	Landing gear	Behavior of model
I. Effect of landing flaps							
Landing flaps deflected	Flight test condition number 1	Full back	Full left	50° down	0	Retracted	Made one or two oscillations in pitch of approximately ±120° measured from the nose-down position, oscillations started to damp out, then dived.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.
J. Effect of landing gear							
Pitch flaps extended	Flight test condition number 1	Full back	Neutral	Neutral	0	Extended	Sometimes tumbled; sometimes oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
K. Effect of pitch flaps							
Pitch flaps deflected	Flight test condition number 1	Full back	Full left	Neutral	26 up	Retracted	Sometimes tumbled; sometimes oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Full forward	----do----	---do--	--do-	----do---	Oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Full back	Neutral	---do--	--do-	----do---	Sometimes tumbled; sometimes oscillated in pitch approximately ±120° measured from the nose-down position until striking safety net.
Do----------	---------do----------	Neutral	----do----	---do--	--do-	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	--do-	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	--do-	----do---	Do.
L. Effect of installing horizontal area equal to 10 percent of the wing area							
Horizontal area equal to 10 percent of the wing area installed on a boom rearward of the model	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Made one or two oscillations in pitch and then dived.
Do----------	---------do----------	------do------	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.
M. Effect of installing horizontal area equal to 5 percent of the wing area							
Horizontal area equal to 5 percent of the wing area installed on a boom rearward of the model	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Made one or two oscillations in pitch, and then dived.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.
N. Effect of installing horizontal area equal to 2 percent of the wing area							
Horizontal area equal to 2 percent of the wing area installed on a boom rearward of the model	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Made one or two oscillations in pitch, and then dived.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Neutral	---do--	0	----do---	Do.
Do----------	---------do----------	Neutral	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full forward	----do----	---do--	0	----do---	Do.
Do----------	---------do----------	Full back	Full right	---do--	0	----do---	Do.

CONFIDENTIAL

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE VI.- TUMBLING CHARACTERISTICS OF THE 1/20-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE WHEN RELEASED WITHOUT ROTATION FROM A HORIZONTAL ATTITUDE AND FROM A NOSE-DOWN ATTITUDE

[Tunnel airspeed for all tests was approximately 75 feet per second]

CONFIDENTIAL

Change from original, clean configuration	Loading	Stick position	Wheel position	Landing flaps	Pitch flaps (deg)	Landing gear	Behavior of model
A. Nose of model approximately 70° below horizontal when released							
None	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Dived with oscillations in pitch of approximately ±15°.
Do------	----do-----	Full forward	----do---	---do--	0	----do---	Do.
Do------	----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do------	----do-----	Neutral	----do---	---do--	0	----do---	Do.
Do------	----do-----	Full forward	----do---	---do--	0	----do---	Do.
Do------	----do-----	Full back	Full right	---do--	0	----do---	Do.
B. Model horizontal when released							
None	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Made one or two oscillations in pitch of approximately ±40° then dived with oscillations rapidly diminishing in amplitude.
Do------	----do-----	Full forward	----do---	---do--	0	----do---	Do.
Do------	----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do------	----do-----	Neutral	----do---	---do--	0	----do---	Do.
Do------	----do-----	Full forward	----do---	---do--	0	----do---	Do.
Do------	----do-----	Full back	Full right	---do--	0	----do---	Do.

CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE VII.- TUMBLING CHARACTERISTICS OF THE 1/20-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE WHEN IMPELLED INTO TUNNEL WITH NOSE SLIGHTLY ABOVE THE HORIZONTAL

[Tunnel airspeed for all tests was approximately 75 feet per second]

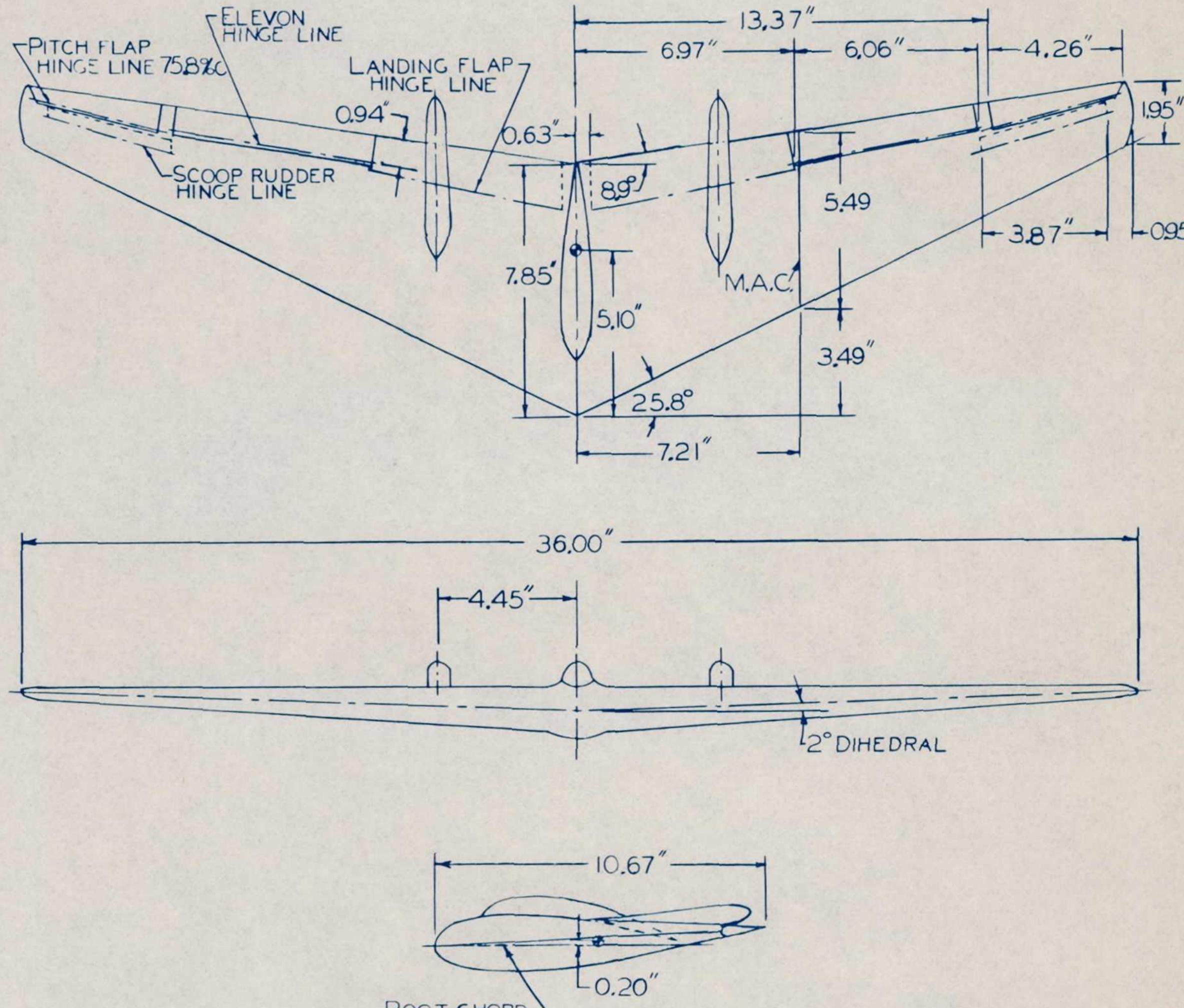
CONFIDENTIAL

Change from original, clean configuration	Loading	Stick position	Wheel position	Landing flaps	Pitch flaps (deg)	Landing gear	Behavior of model
None	Flight test condition number 1	Full back	Full left	Neutral	0	Retracted	Made one or two oscillations in pitch of approximately $\pm 60^{\circ}$ then dived with oscillations rapidly diminishing in amplitude.
Do------	----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do------	----do-----	Full back	Neutral	---do--	0	----do---	Do.
Do------	----do-----	Neutral	----do----	---do--	0	----do---	Do.
Do------	----do-----	Full forward	----do----	---do--	0	----do---	Do.
Do------	----do-----	Full back	Full right	---do--	0	----do---	Do.

CONFIDENTIAL

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

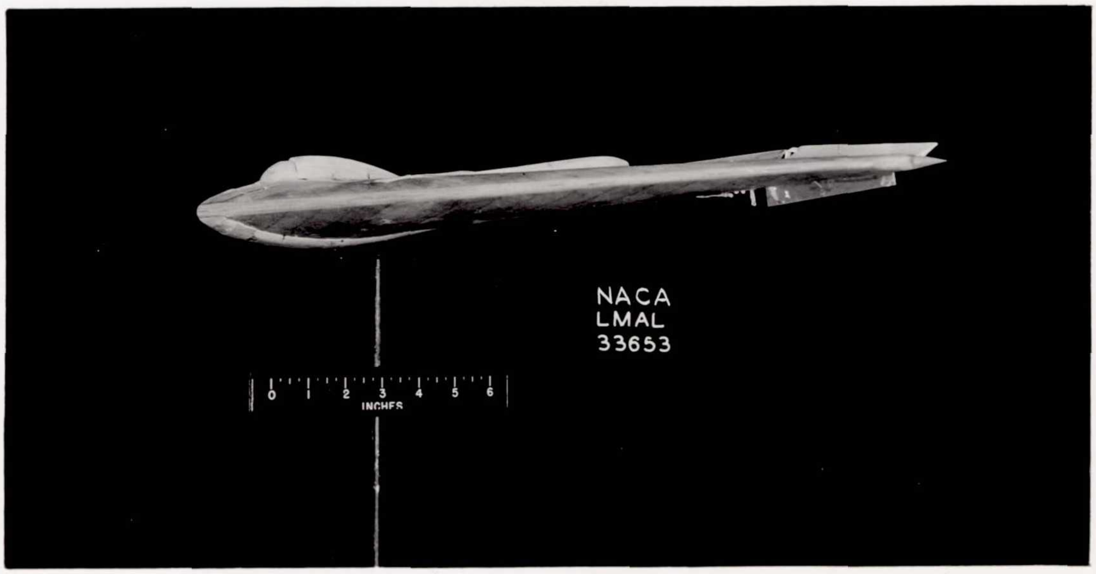
CONFIDENTIAL



CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

FIGURE 1.- THREE-VIEW DRAWING OF THE $\frac{1}{20}$-SCALE MODEL OF THE NORTHROP N-9M AIRPLANE AS TESTED IN THE 20 FOOT FREE-SPINNING TUNNEL. CENTER OF GRAVITY SHOWN FOR FLIGHT TEST CONDITION NUMBER 1.



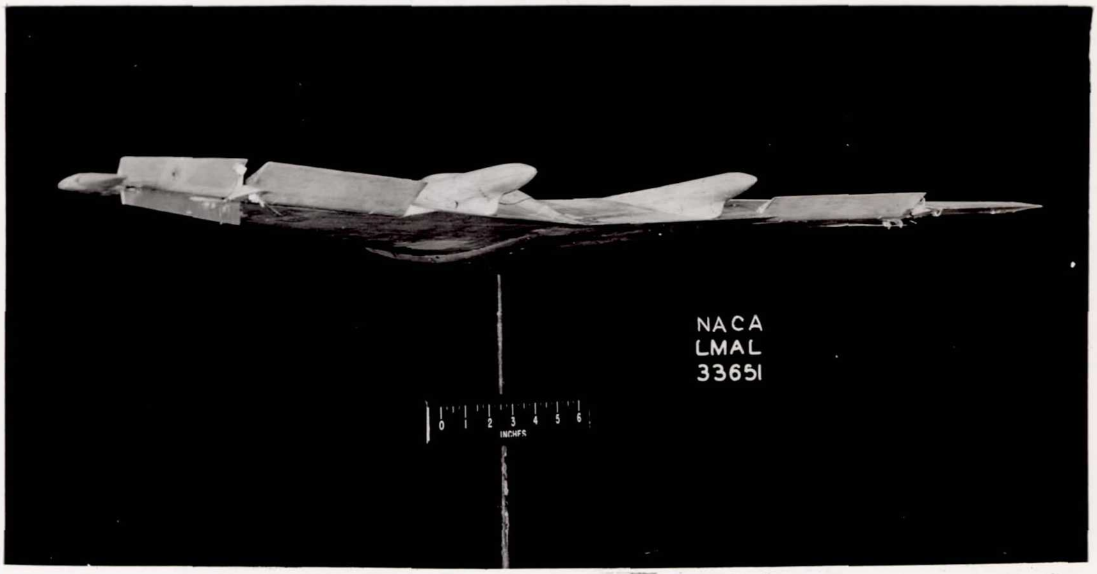


Figure 2.- A $\frac{1}{20}$-scale model of the Northrop N-9M airplane as tested in the 20-foot free-spinning tunnel in the clean configuration.

CONFIDENTIAL

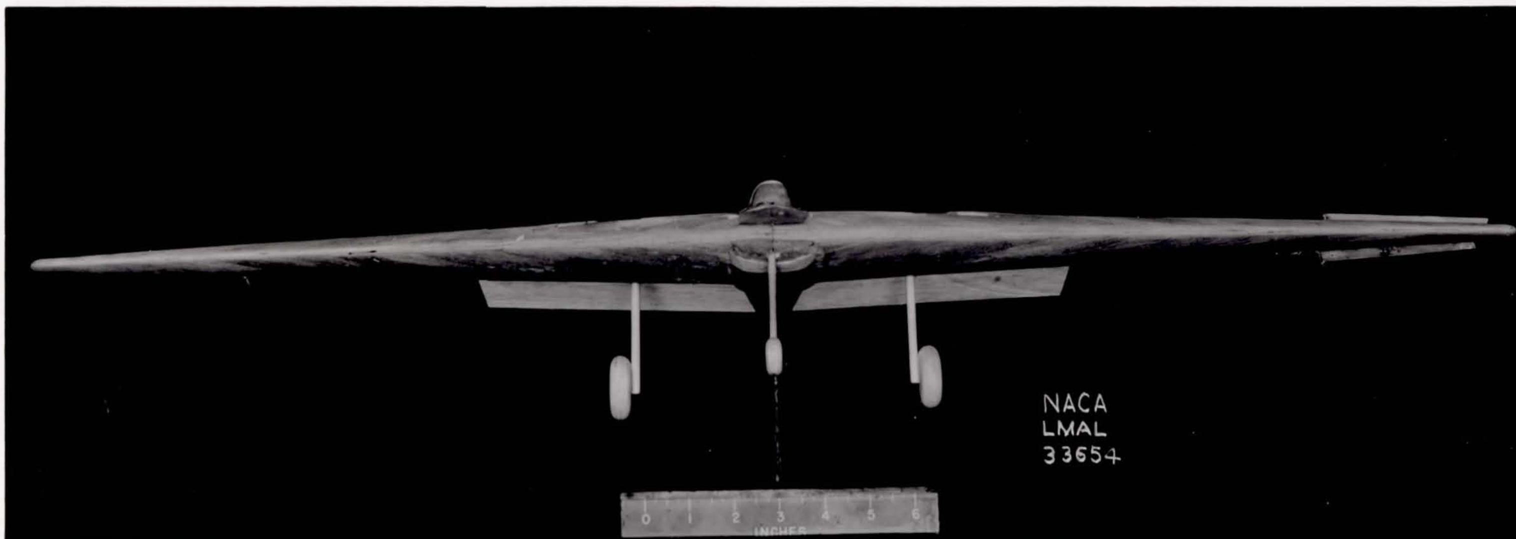
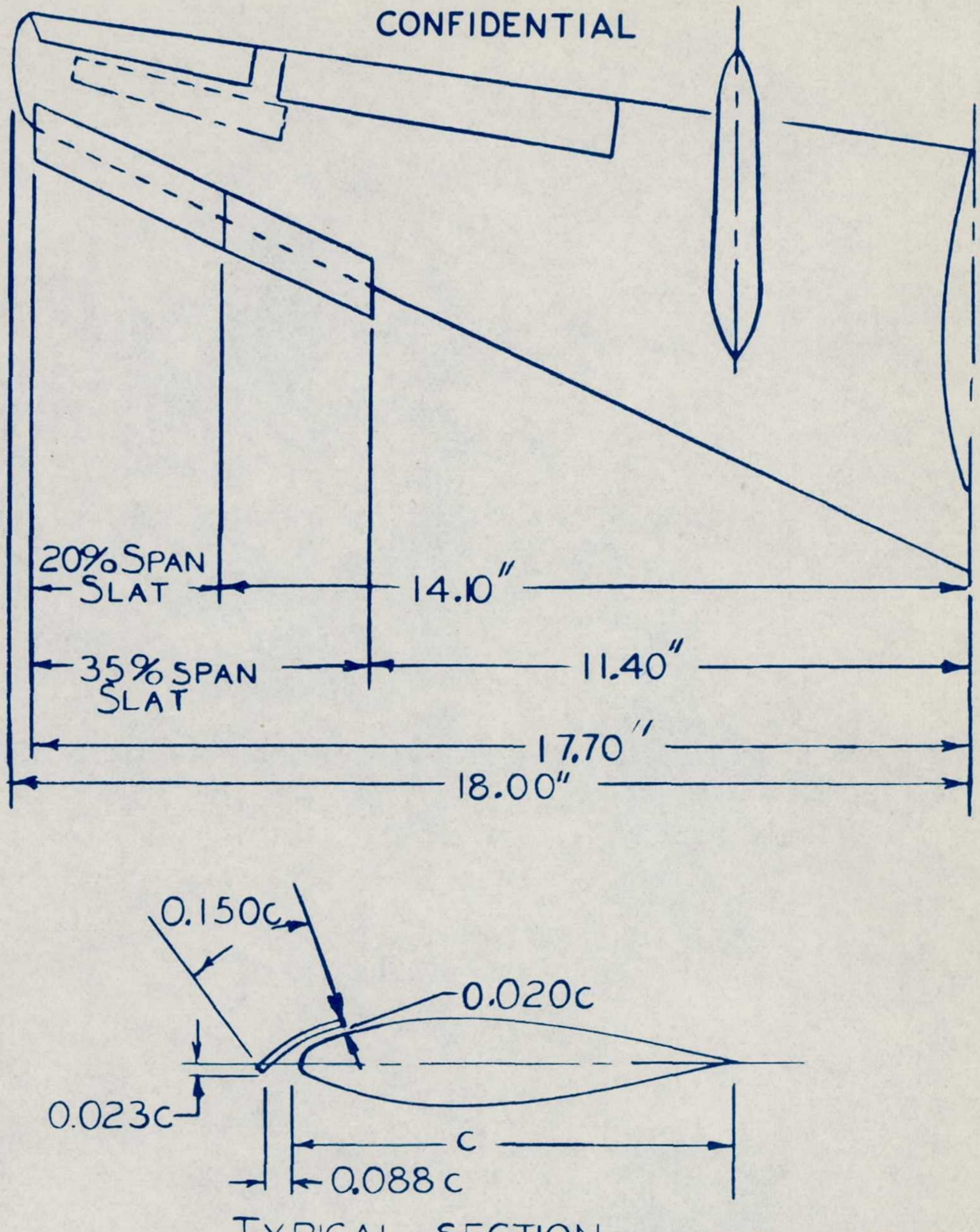


Figure 3.- A $\frac{1}{20}$-scale model of the Northrop N-9M airplane as tested in the 20-foot free-spinning tunnel in the landing configuration.

CONFIDENTIAL

CONFIDENTIAL

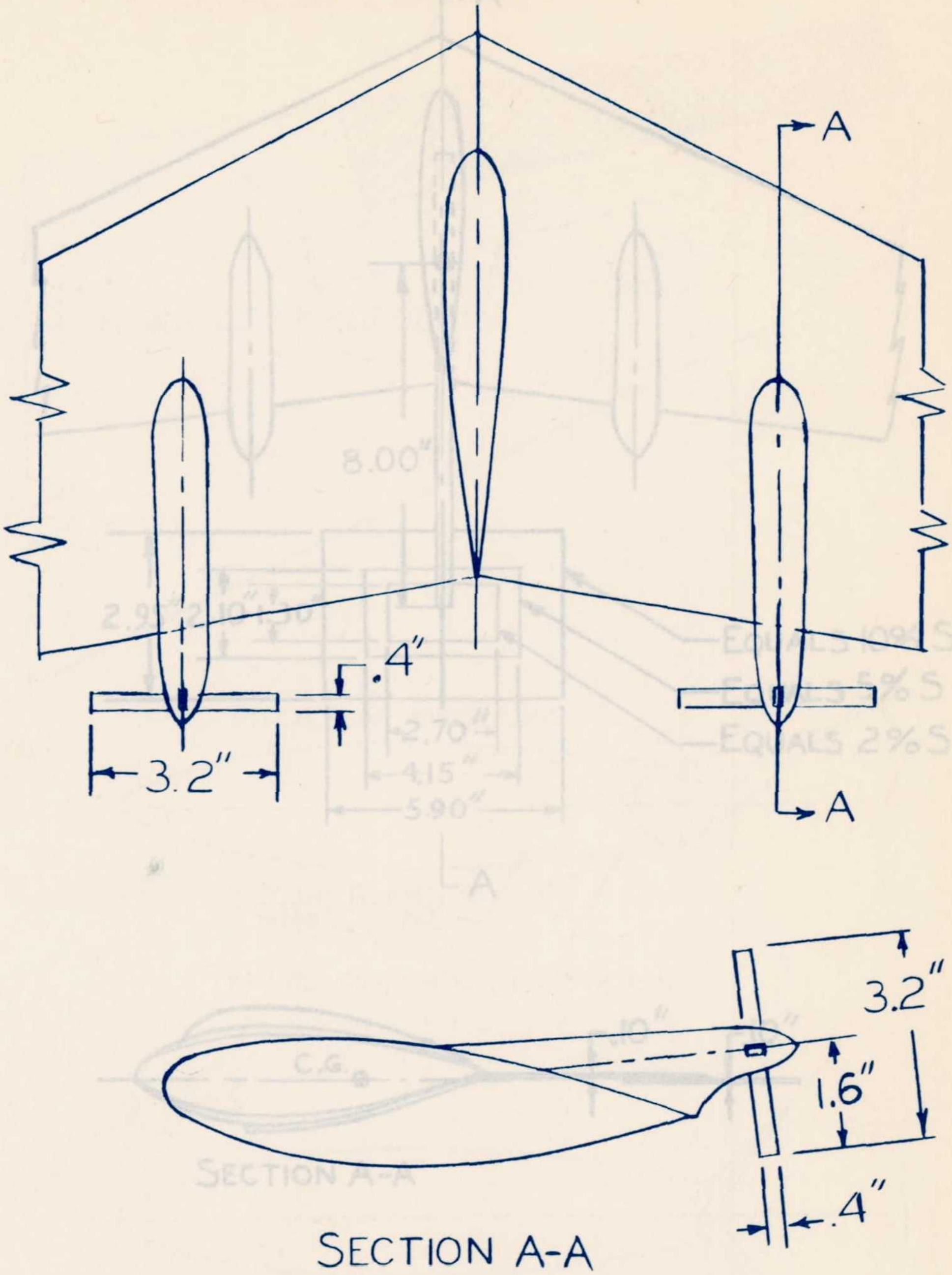


NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL

FIGURE 4.-SIMULATED SLATS TESTED ON THE $\frac{1}{20}$-SCALE MODEL OF THE NORTHROP N-9M AIRPLANE.

CONFIDENTIAL

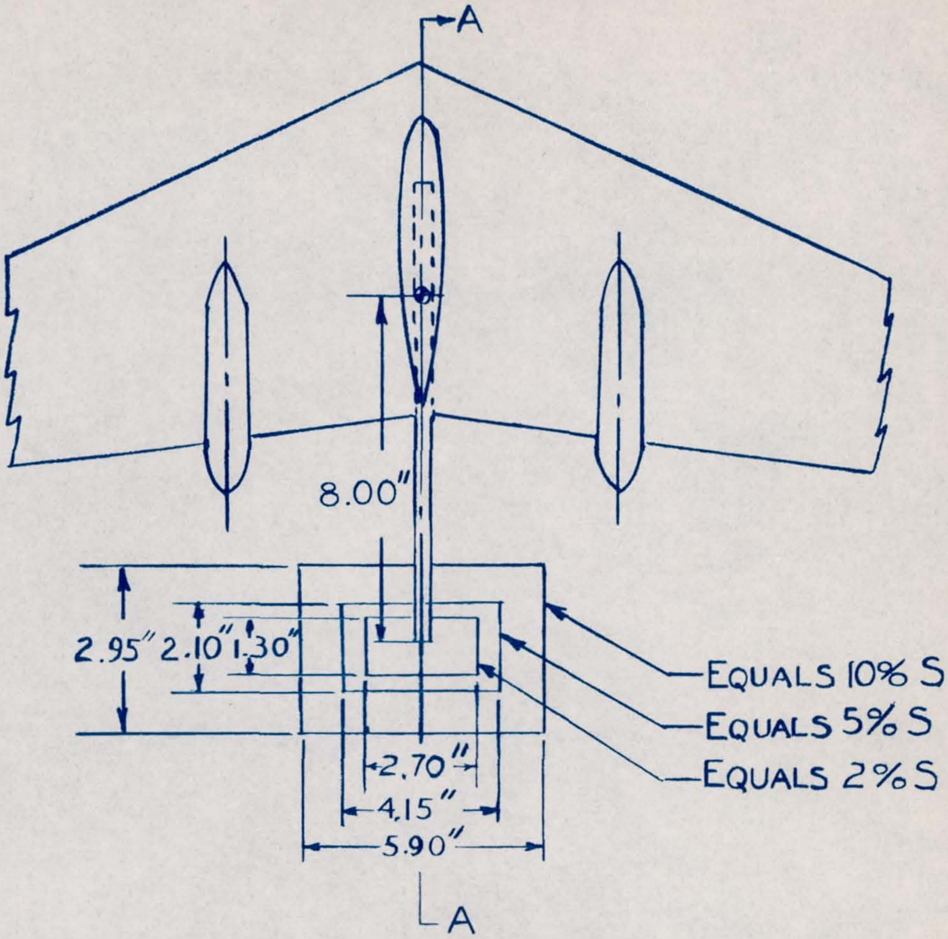


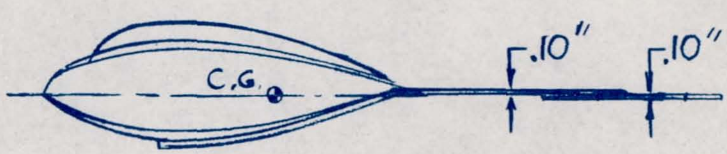
SECTION A-A

CONFIDENTIAL

FIGURE 5.- EQUIVALENT PROPELLER FIN AREA AS TESTED ON THE $\frac{1}{20}$-SCALE MODEL OF THE NORTHROP N-9M AIRPLANE.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS



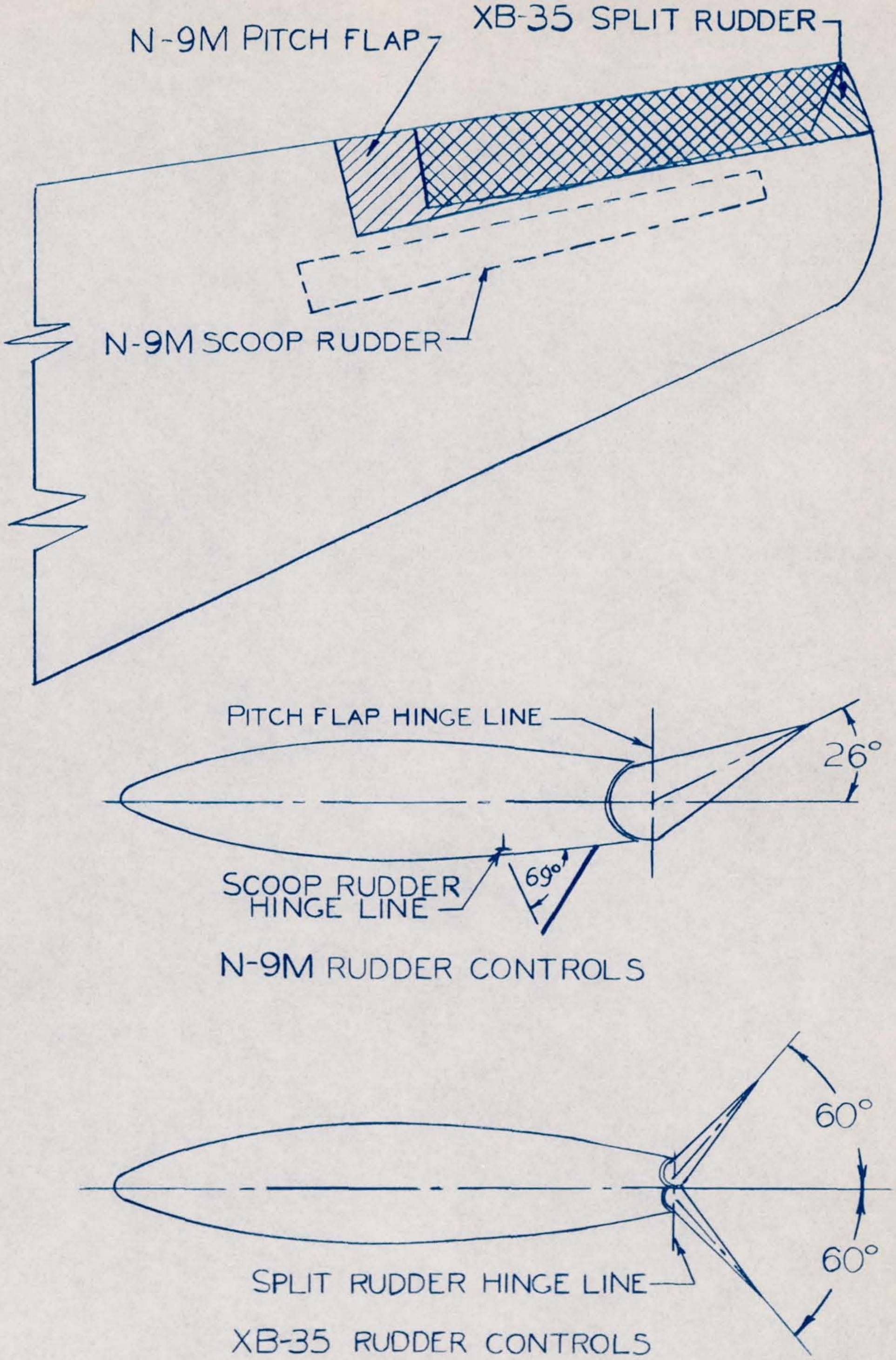


SECTION A-A

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

FIGURE 6.- INSTALLATION OF HORIZONTAL AREAS ON A $\frac{1}{20}$-SCALE MODEL OF THE NORTHROP N-9M AIRPLANE.

CONFIDENTIAL

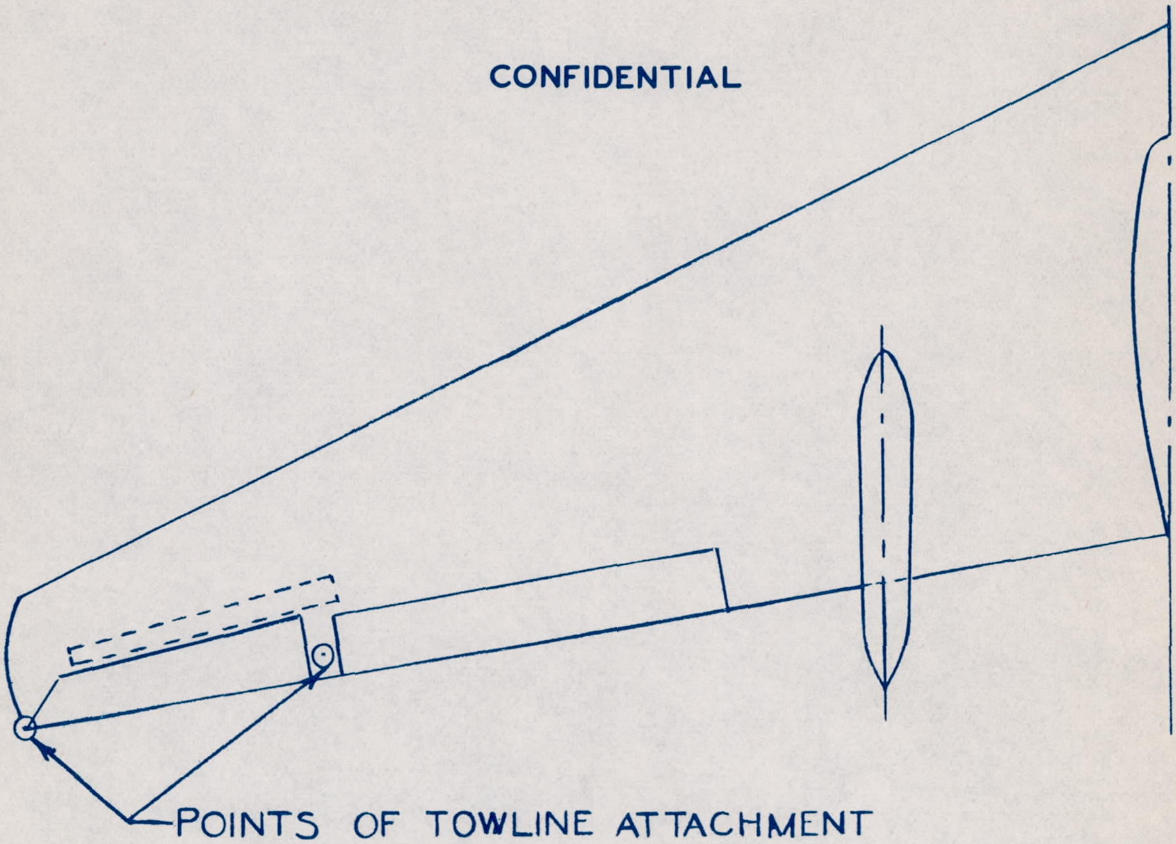


CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

FIGURE 7.-COMPARISON OF THE RUDDER CONTROLS OF THE NORTHROP N-9M AND XB-35 AIRPLANES.

CONFIDENTIAL

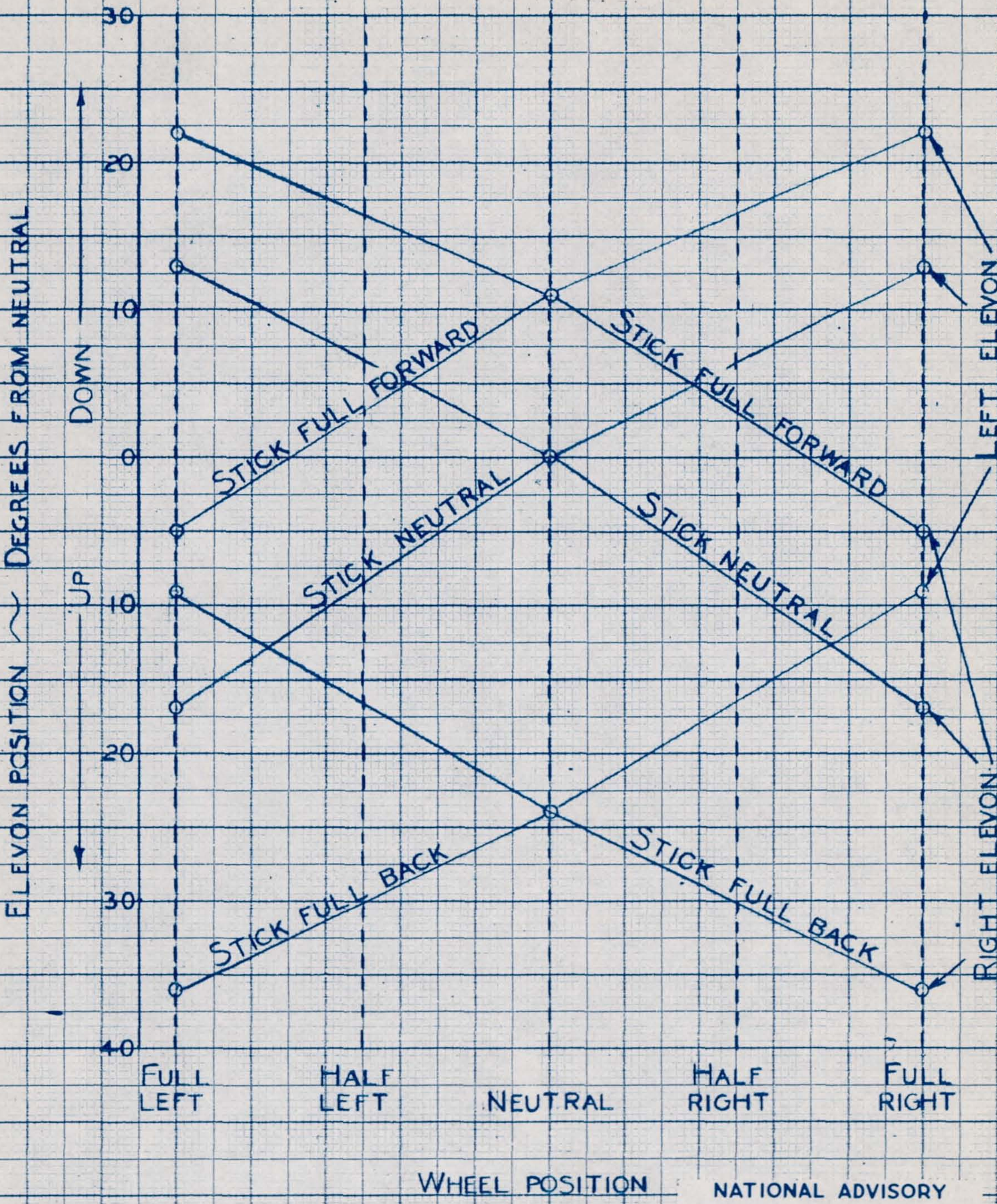


CONFIDENTIAL

FIGURE 8.- LOCATION OF THE POINTS OF TOWLINE ATTACHMENT FOR THE PARACHUTE TESTS ON A $\frac{1}{20}$-SCALE MODEL OF THE NORTHROP N-9M AIRPLANE.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL



NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

FIGURE 9.- ELEVON DEFLECTIONS USED ON THE $\frac{1}{20}$-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE FOR VARIOUS COMBINATONS OF STICK AND WHEEL POSITIONS.

CONFIDENTIAL

CONFIDENTIAL

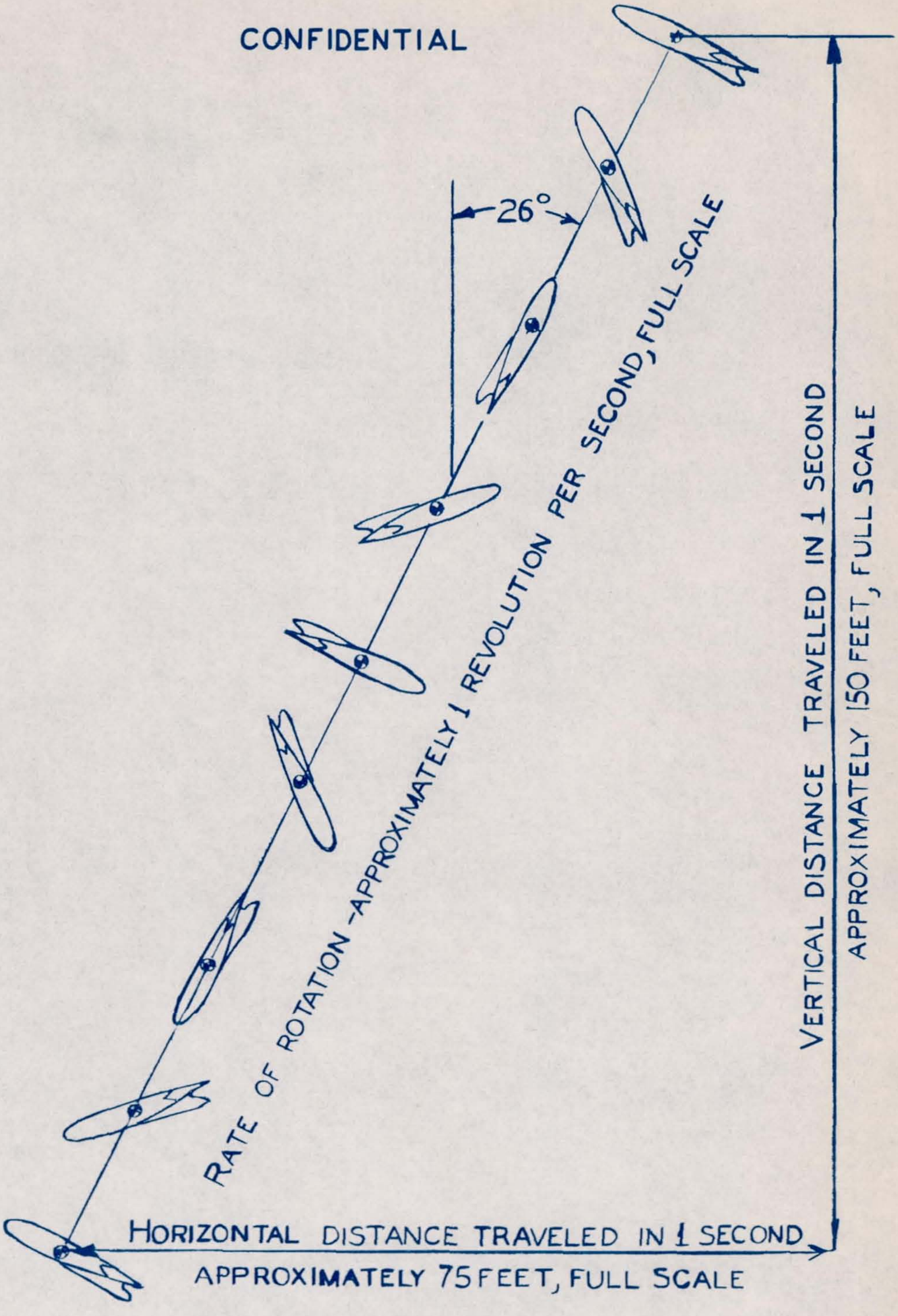


FIGURE 10.- TYPICAL PATH OF THE $\frac{1}{20}$-SCALE MODELS OF THE NORTHROP N-9M AIRPLANE DURING A TUMBLE.

CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Figure 11.- Typical tumble of the $\frac{1}{20}$-scale models of the Northrop N-9M airplane when released from a nose-up attitude. Clean configuration, stick full back, wheel neutral, scoop rudders and pitch flaps neutral. Camera speed, 64 frames per second. Velocity of airstream, approximately 75 feet per second, full-scale.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY MEMORIAL AERONAUTICAL LABORATORY – LANGLEY FIELD, VA.

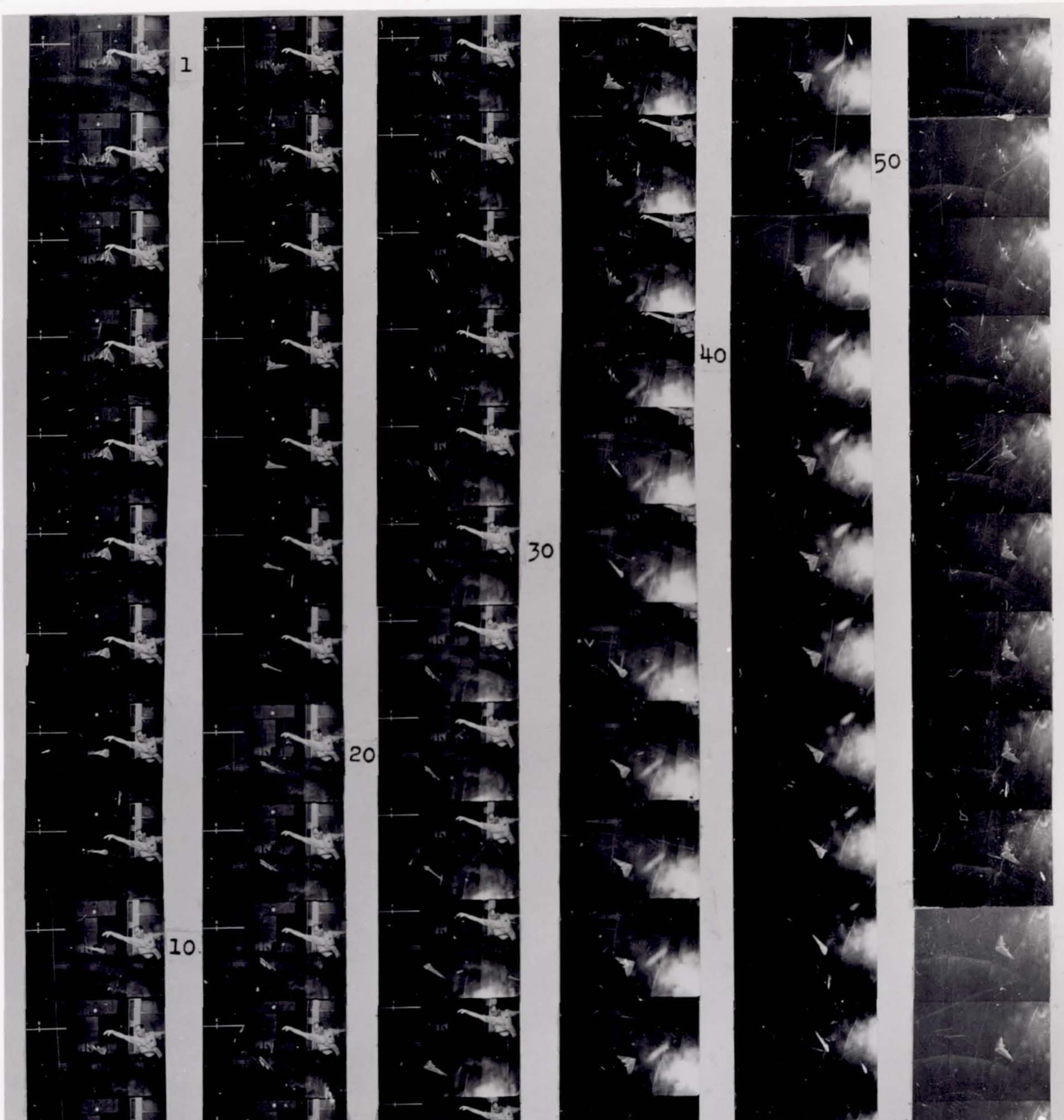


Figure 12.- Typical oscillatory motion of the $\frac{1}{20}$-scale models of the Northrop N-9M airplane when released from a nose-up attitude. Clean configuration, stick neutral, wheel neutral, scoop rudders and pitch flaps neutral. Camera speed, 64 frames per second. Velocity of airstream, approximately 75 feet per second, full-scale.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY MEMORIAL AERONAUTICAL LABORATORY - LANGLEY FIELD, VA.

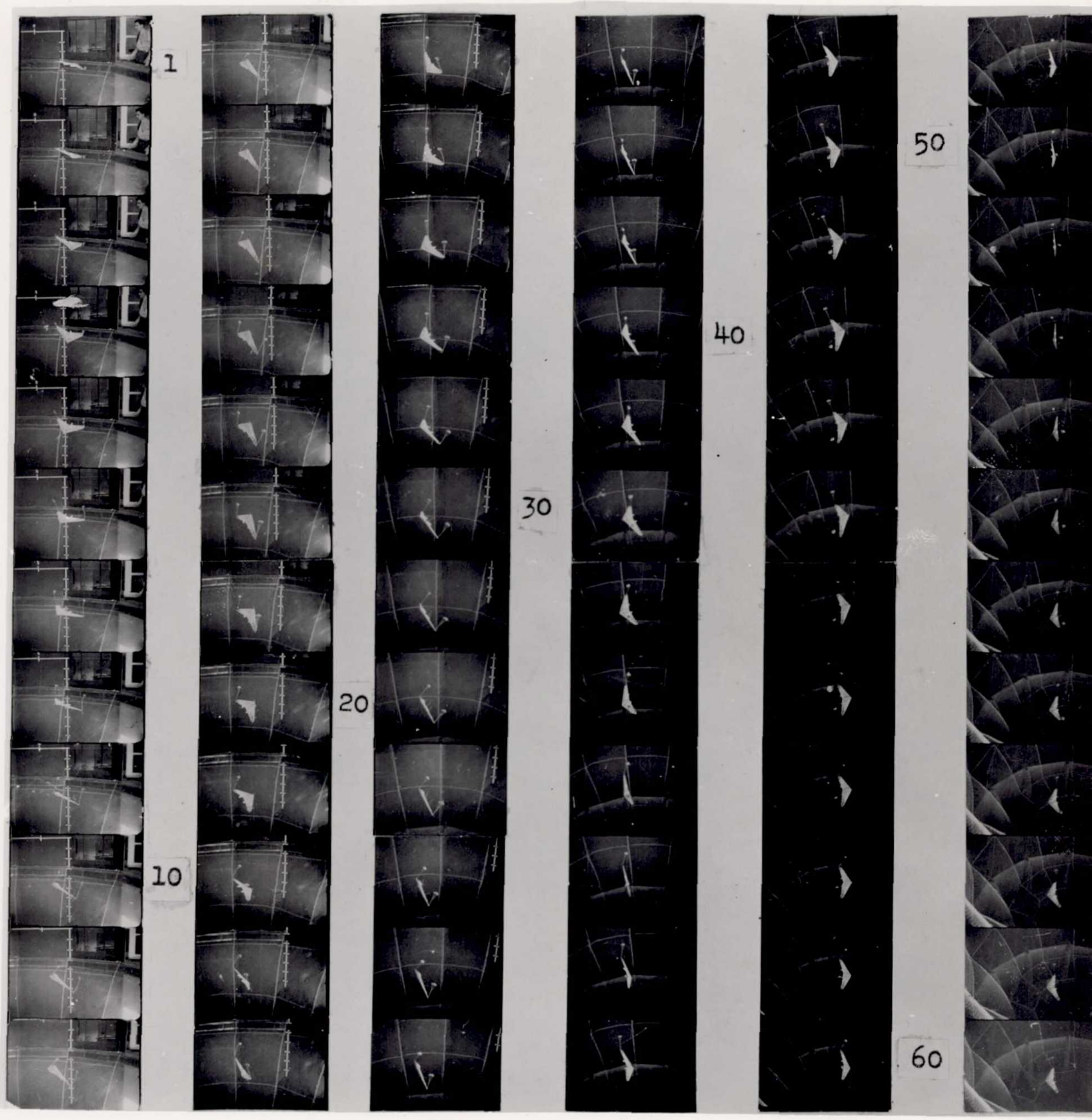


Figure 13.- Typical action of parachutes in producing recovery from an established tumble on the $\frac{1}{20}$-scale models of the Northrop N-9M airplane. Clean configuration, stick neutral, wheel neutral, scoop rudders and pitch flaps neutral. Camera speed, 64 frames per second. Velocity of airstream, approximately 85 feet per second, full-scale. Towlines attached to rear portion of wing tips. Parachute diameter, 7 feet full-scale. Parachute drag coefficient, approximately 0.7. Towline length, 10 feet full-scale.

[redacted]