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RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION OF THE STABILITY OF THE JETTISONABLE NOSE SECTION OF THE X-3 AIRPLANE

By

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RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION OF THE STABILITY OF THE JETTISONABLE NOSE SECTION OF THE X-3 AIRPLANE

By Stanley H. Scher

SUMMARY

Because previous work has indicated that jettisonable nose sections of airplanes may be inherently unstable, and thus may cause dangerous centripetal accelerations on a pilot after jettisoning during high-speed flight, an investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the behavior in descent of a model of the jettisonable nose section of the Douglas X-3 airplane. The effects of varying the center-of-gravity position, of attaching fins of various sizes, and of installing a stabilizing parachute were investigated.

In the investigation the model descended with its front end trimmed 36° above the horizontal and rotated about a vertical wind axis while rolling about its longitudinal body axis. The nose section was made to descend in a stable front-down attitude when stabilizing fins were installed in conjunction with movement of the center of gravity forward or when a stable parachute was attached to the model.

INTRODUCTION

The NACA is conducting a general investigation of methods of pilot escape from high-speed aircraft. One method that has been proposed for the X-3 airplane and for several other recent designs is to jettison the nose of the airplane at a break-off station immediately rearward of the pilot; after the nose has been jettisoned and its speed has decreased, the pilot would leave the nose section and descend with his personal parachute. Spin-tunnel experience with models of jettisonable nose sections of airplanes (references 1 and 2) has indicated that the noses may be inherently unstable, and when jettisoned at high airspeeds may undergo rapid rotations which may cause dangerous accelerations on the pilot. The behavior of the jettisonable nose of the X-3 airplane has been investigated at low speeds through tests of a $\frac{1}{23}$-scale model

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of the nose in the Langley 20-foot free-spinning tunnel and the results are presented herein. The model simulated the nose section during its descent toward the ground, assuming that it had been jettisoned clear of the main body of the airplane. The effects on stability of varying the center-of-gravity location, of attaching fins of various sizes, and of installing a stabilizing parachute were investigated.

Although it is understood that the design of the proposed jettisonable nose of the X-3 airplane has been altered since the present investigation was completed, it is felt that the results presented herein will be of general interest to the contractor and to other agencies concerned with the problem of pilot escape at high airspeeds.

SYMBOLS

L — length of nose section, inches (all center-of-gravity locations are expressed as a percentage of this length from the front end of the nose section)

X, Y, Z — longitudinal, lateral, and normal axes, respectively, through center of gravity of nose

I_X, I_Y, I_Z — full-scale values of moments of inertia about the X-, Y-, and Z-axes, respectively, slug-feet^2

ρ — air density, slugs per cubic foot

V — full-scale airspeed, feet per second

F — projected full-scale frontal area of nose section, square feet (19.0 for X-3 nose)

C_D — drag coefficient of nose section $\left(\frac{\text{Drag}}{\frac{1}{2}\rho V^2 F}\right)$

r — distance between axis of rotation and pilot's head, feet

Ω — rate of rotation of nose section, radians per second

g — acceleration due to gravity, 32.2 feet per second squared

a_c — centripetal acceleration, feet per second squared $\left(r\Omega^2\right)$

APPARATUS AND METHODS

Model

A $\frac{1}{23}$-scale model of the jettisonable nose section of the X-3 airplane was constructed and prepared for testing at the Langley Laboratory. Photographs of the model are shown in figure 1 and a sketch of the model is shown in figure 2. The dimensions of various fins tested on the model are presented in figure 3. The model was ballasted with lead weights to approximate dynamic similarity to the airplane nose section at an altitude of 15,000 feet ($\rho = 0.001496$ slug per cubic foot). The weight, center-of-gravity location, and moments of inertia of the airplane nose section were obtained from information furnished by the contractor, and the mass characteristics of the model as tested are presented in table I in terms of the full-scale nose section.

Wind Tunnel and Testing Technique

The tests were made in the Langley 20-foot free-spinning tunnel, the operation of which is, in general, similar to that described in reference 3 for the Langley 15-foot free-spinning tunnel, except that models are now launched into the vertically rising air stream by hand rather than from a spindle. A photograph showing the Langley 20-foot free-spinning tunnel and the model being tested is shown as figure 4. The tests included launchings in which the model was held in the air stream at various angles of attack from 0° to 180°, and then released, and launchings in which the model was given rotation about each of its three axes with the axes held alternately parallel with and perpendicular to the air stream. The behavior of the model after each launching was observed visually and, in addition, motion pictures were taken of the tests.

In accordance with the present technique used in testing models of jettisonable nose sections, various combinations of center-of-gravity location and fin installations were tested to determine arrangements which would make the model damp any applied rotation and descend in a stable front-down attitude. All values of rates of rotation and rates of descent as presented herein have been converted by methods similar to those explained in reference 3 to full-scale values for the airplane nose section at an altitude of 15,000 feet. Because of possible scale effects, the actual rates of rotation of the full-scale nose section may be somewhat different than the values presented. For cases in which the model traveled with its front end down in the tunnel, no value for the rate of descent is given because it exceeded the maximum airspeed of the tunnel, which for the $\frac{1}{23}$-scale model tested, represents a full-scale value of 479 feet per second (327 miles per hour).

TEST CONDITIONS AND PRECISION

The fin arrangements and center-of-gravity locations tested on the model are indicated in table II. The mass characteristics for the various center-of-gravity locations are listed in table I.

The accuracy of measuring the weight and mass distribution of the model is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, inches	±0.01
Moments of inertia, percent:	
I_X	±15
I_Y	±5
I_Z	±5

RESULTS AND DISCUSSION

The results of the tests are presented in table II.

Original condition.- When the model in its original condition (c.g. at 0.719L, no fins installed) was dropped into the rising air stream at any angle of attack, it immediately began making irregular oscillatory and sidewise movements in the tunnel. The model soon went into a condition of equilibrium during which it rotated at a rate of 2.85 radians per second, full scale, about a vertical wind axis with the front of the model trimmed 36° above horizontal and at the same time it rolled about its longitudinal body axis at a rate of 2.50 radians per second, full scale. The model is shown in the equilibrium condition in the motion-picture strips in figure 5. The equilibrium condition represents the behavior of the nose section after it has cleared the rest of the airplane and reached its terminal rate of descent of 242 feet per second, full scale. When the model was launched with applied rotation, it soon damped the rotation and went into the equilibrium condition. Both axes about which the model rotated while in the equilibrium condition appeared to be approximately through the model center of gravity. Inasmuch as in the full-scale nose section the pilot is

[redacted]

located near the center of gravity, the resulting centripetal acceleration a_c acting on him as a result of the rotations will be very small (less than 1 negative longitudinal g at pilot's head due to rolling rotation). Although determination of the behavior of the nose section at high speeds is beyond the scope of the present investigation, it is possible that when jettisoned at high speeds the rotations of a nose which is unstable at low speeds may be at correspondingly faster rates and the accelerations may therefore be higher and dangerous to a pilot. Reference 4 contains a discussion of the effects of acceleration on a man's body.

Effect of center-of-gravity location.- When the center of gravity was moved forward from its original location of 0.719L to 0.574L, the model sometimes descended stably with its front end down and sometimes descended in a condition similar to the previously described equilibrium condition regardless of the method of launching. When the center of gravity was moved to 0.464L and the model was released into the air stream without applied rotation, the model descended stably with its front end down; however, when launched with rotation about the normal body axis with the axis held parallel to the air stream, the model nearly always descended stably with its front end down, but occasionally it descended in a condition generally similar to the previously described equilibrium condition. These results are in general agreement with the results of previous free-spinning-tunnel tests (reference 1) of a model of a symmetrical jettisonable nose which indicated that unless stabilizing fins were installed, the model was unstable even when its center-of-gravity was as far forward as 0.31L; however, the X-3 model showed a greater tendency to descend stably front down than did the aforementioned symmetrical model.

Effect of fin area.- For the original center-of-gravity location (0.719L), the addition of fins was not sufficient to make the model assume a front-down attitude, even when the fins were of very large size. With the fins installed, the model trimmed at a high angle of attack and rolled about its longitudinal axis at faster rates than it did with no fins installed; however, the model did not rotate about a vertical wind axis as it did with no fins installed. With fins of large area (fin arrangements C, D, or E in fig. 3) installed, the rate of rotation of the model about its longitudinal axis was faster than it was with smaller fins (arrangements A or B) installed, and the resulting centripetal acceleration at a pilot's head would be about 2 negative longitudinal g. This acceleration is somewhat more than that resulting from the previously described equilibrium condition obtained with no fins installed. The model is shown rolling about its longitudinal axis, after rotation applied about its normal axis has been damped, in the motion-picture strips of figure 7.

When fin arrangement B was installed and the center of gravity was moved forward to 0.574L, the model nose section damped any applied rotation and descended in a front-down stable attitude. The same result was obtained when larger fins C were installed and the center of gravity was moved forward to only 0.632L. These results are in agreement with those of references 1 and 2, which indicate that if the center of gravity of a nose section is not too far back from its front, the nose can be made to descend in a front-down stable attitude by installing suitable fins rearward of the center of gravity and that the amount of fin area required for front-down descent decreases as the center of gravity is moved forward.

Effect of fin aspect ratio.- Because results of previous work (reference 2) indicated that an increase in fin aspect ratio may have a beneficial effect on the stability of nose section models, brief tests were made to determine the effect of increasing fin aspect ratio for the X-3 nose model with the original center-of-gravity location (0.719L). For these tests, triangular fins of aspect ratio 2 (fin arrangement F in fig. 3) having the same area as fin arrangement C (aspect ratio 1) were installed on the model. The stability of the model with the increased-aspect-ratio fins was not appreciably improved over its stability with the lower-aspect-ratio fins, although the rate of rotation about the longitudinal axis was slightly less.

Stabilizing parachutes.- With the model in its original condition without fins, brief tests were made in which a stable-type parachute on the end of a towline was attached to the center of the back end (break-off station) of the nose section of the model. The model then descended in a front-down stable attitude. The stable parachute used was a hemispherical-type high-porosity parachute with a projected hemispherical diameter of 8.1 feet (full scale). The shroud lines were 24.3 feet long and the towline was 8.1 feet long (full-scale values). This parachute had a drag coefficient of 1.11, based on its projected hemispherical diameter, and the full-scale equilibrium rate of descent of the nose and parachute was 269 feet per second (183 mph). By varying the diameter, drag coefficient, or towline length of a stable parachute, any desired equilibrium rate of descent of the nose section should be obtainable. The present result is in agreement with results presented in references 1 and 2 which indicate that airplane jettisonable nose sections can be made to descend in a stable front-down attitude by use of a stable parachute. As indicated in references 1 and 2, however, some problems which must be considered in connection with use of a stabilizing parachute at high speeds are: (1) fouling of the parachute on the remainder of the airplane during separation, (2) possibility of dangerous rotations developing before the parachute opens, and (3) shock loads connected with opening of the parachute.

CONCLUSIONS

Based on results of tests made in the Langley 20-foot free-spinning tunnel on a $\frac{1}{23}$-scale model of the jettisonable nose section of the X-3 airplane, the following conclusions are drawn regarding the behavior of the airplane nose section:

1. After reaching its equilibrium rate of descent, the nose section will descend with its front trimmed 36° above horizontal while rotating both about a vertical wind axis and about its longitudinal body axis.

2. The nose section can be made to descend in a stable front-down attitude by installing stabilizing fins in conjunction with movement of the center of gravity forward or by use of a stable parachute.

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National Advisory Committee for Aeronautics
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Approved:
Thomas A. Harris
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MMC

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

4. 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.- FULL-SCALE VALUES OF MASS CHARACTERISTICS

FOR THE CENTER-OF-GRAVITY LOCATIONS TESTED ON

THE $\frac{1}{23}$-SCALE MODEL OF THE JETTISONABLE NOSE

SECTION OF THE X-3 AIRPLANE

Center-of-gravity location (percent length from front)	Weight (lb)	Moments of inertia about the center of gravity		
		I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)
71.9 (original)	2710	79	2000	2000
63.2	2766	185	4329	4235
57.4	2749	58	4700	4733
46.4	2782	254	8498	8523

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TABLE II.- RESULTS OF FREE-SPINNING-TUNNEL TESTS OF A $\frac{1}{25}$-SCALE MODEL OF THE JETTISONABLE NOSE SECTION OF THE X-3 AIRPLANE

[Rates of descent and of rotation are given in terms of full-scale values]

Condition	Center-of-gravity location (percent length from front)	Fin arrangement on nose			Description of motion of model during descent
		Designation (see fig. 3)	Number of fins	Positions on cross section of break-off station (a)	
1	71.9	None	-	----------	Model trimmed with front approximately 36° above horizontal and rotated at 2.85 radians per second about a vertical wind axis while rolling about longitudinal body axis at 2.50 radians per second (rate of descent was 242 ft per sec or 165 mph); C_D was 3.25
2	57.4	None	-	----------	Model sometimes lost any applied rotation and descended in front-down stable attitude; model sometimes trimmed with front approximately 30° below horizontal and rotated at 2.07 radians per second about a vertical wind axis while rolling about longitudinal body axis at approximately 2 radians per second (rate of descent was approximately 259 ft per sec or 177 mph)
3	46.4	None	-	----------	Model nearly always lost any applied rotation and descended in front-down stable attitude; model occasionally trimmed with front approximately 25° below horizontal and rotated at 2.27 radians per second about a vertical wind axis while rolling about longitudinal body axis at approximately 4 radians per second (rate of descent was approximately 220 ft per sec or 150 mph)
4	71.9	A	3	2, 6, 10 o'clock	Model traveled backward across tunnel and rolled about its longitudinal body axis at 1.84 radians per second; model made occasional pitching motions during which front went 17° above and below horizontal (rate of descent was 259 ft per sec or 176.5 mph)
5	71.9	B	3	2, 6, 10 o'clock	Do.
6	71.9	C	3	4, 8, 12 o'clock	Model sometimes traveled forward across tunnel and rolled about its longitudinal body axis at approximately 6 radians per second while its front was pitching ±11° from horizontal (rate of descent was 192.5 ft per sec or 131 mph); model sometimes lost any applied rotation and descended in front-down stable attitude
7	71.9	D	3	4, 8, 12 o'clock	Do.
8	71.9	E	4	3, 6, 9, 12 o'clock	Do.
9	71.9	F	3	4, 8, 12 o'clock	Model sometimes traveled forward across tunnel and rolled about its longitudinal body axis at 4.5 radians per second while its front was pitching 20° above and 30° below horizontal (rate of descent was 206 ft per sec or 140 mph); model sometimes lost any applied rotation and descended in front-down stable attitude.
10	57.4	A	3	2, 6, 10 o'clock	Model lost any applied rotation and descended in front-down stable attitude
11	63.2	B	3	2, 6, 10 o'clock	Similar to condition 6, except rate of rotation was approximately 2 radians per second; also, one time model descended in front-vertically-up stable attitude (180° angle of attack)
12	63.2	B	3	4, 8, 12 o'clock	Similar to condition 6, except rate of rotation was approximately 2 radians per second; however, better than conditions 6 or 11 in that stable front-down descent occurred relatively more times
13	63.2	C	3	4, 8, 12 o'clock	Model lost any applied rotation and descended in front-down stable attitude
14	63.2	E	4	3, 6, 9, 12 o'clock	Do.

[a]For three-fin arrangements, alternate fin positions of 2, 6, 10 o'clock and 4, 8, 12 o'clock were given by contractor.

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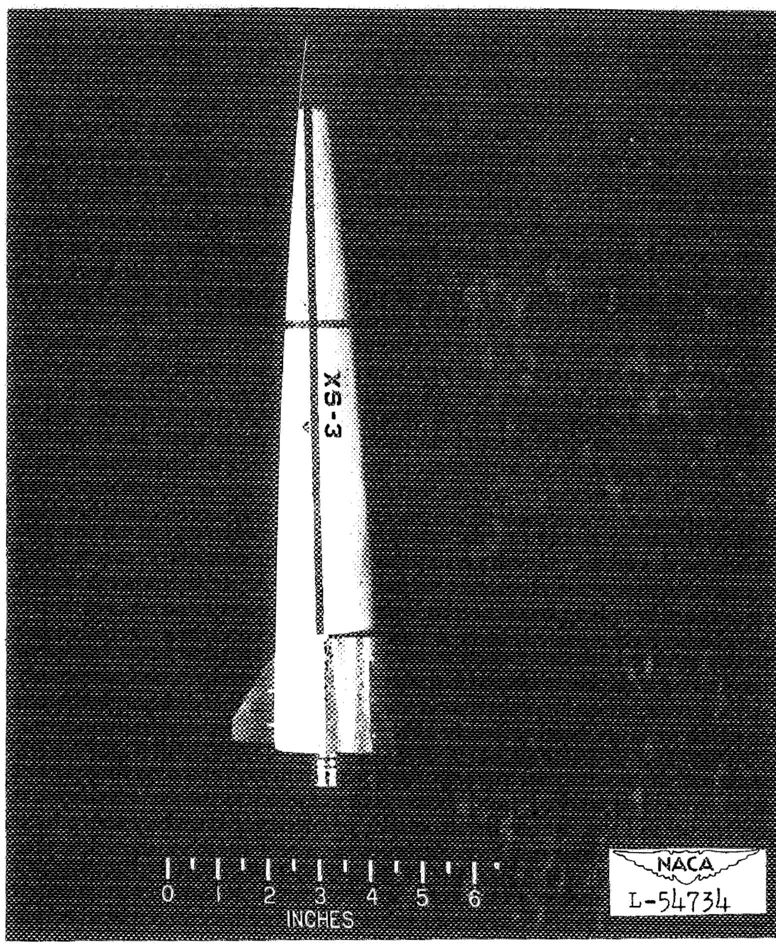

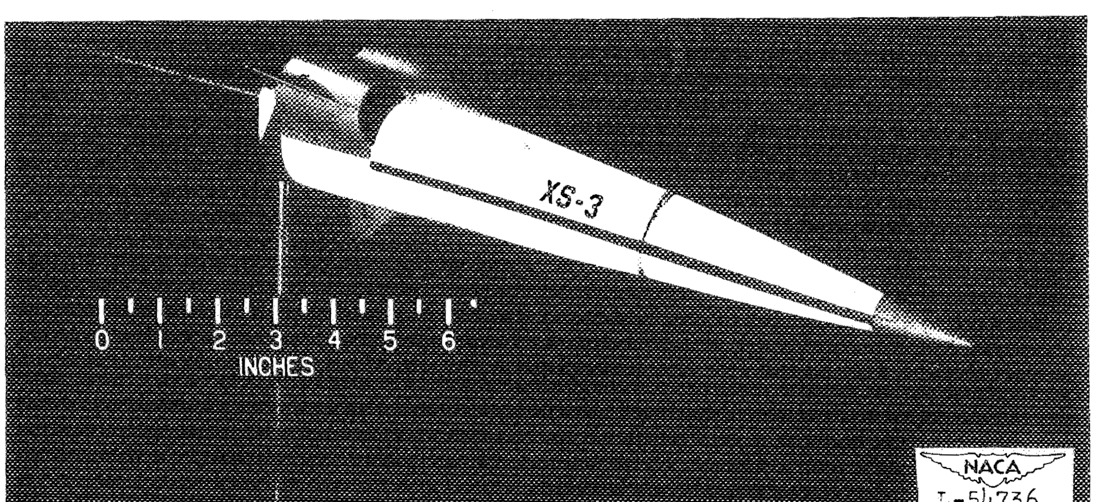

Figure 1.- Photographs of the $\frac{1}{23}$-scale model of the jettisonable nose of the X-3 airplane tested in the Langley 20-foot free-spinning tunnel.

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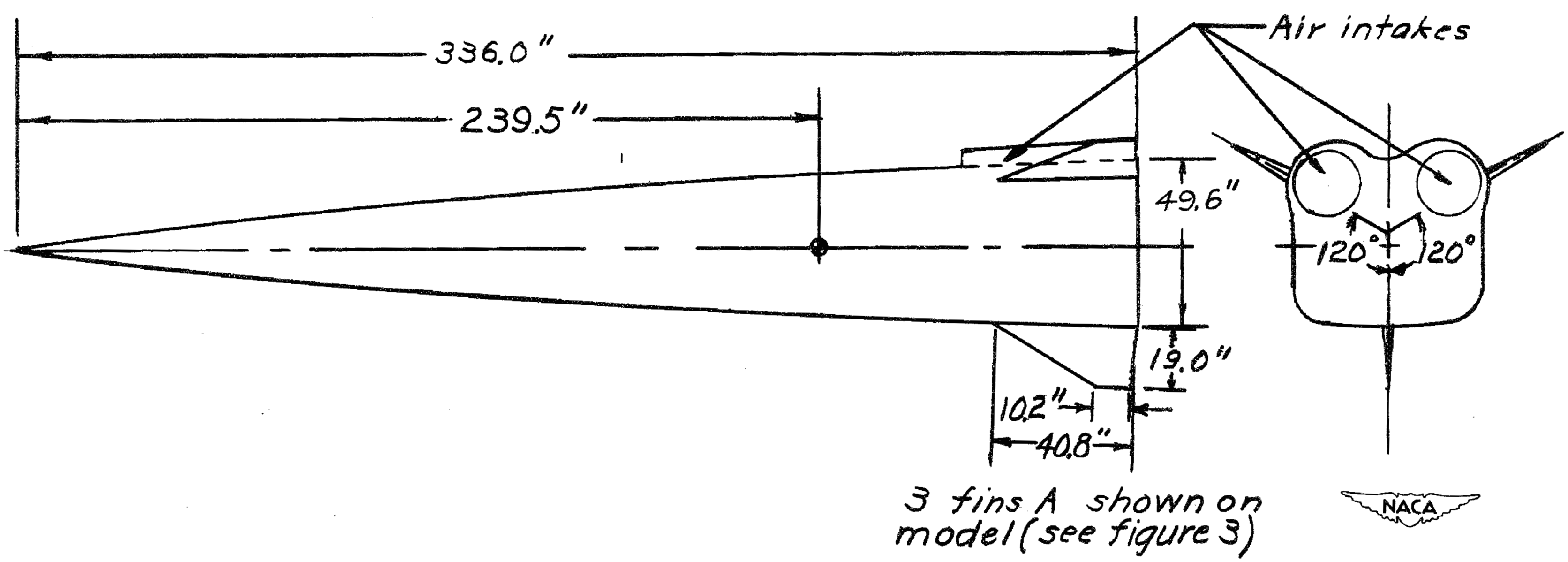

Figure 2.- Sketch of the $\frac{1}{23}$-scale model of the jettisonable nose section of the Douglas X-3 airplane tested in the free-spinning tunnel. Dimensions are full-scale values. Center of gravity shown in original position.

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Table of fin dimensions

Fin designation	Span, b in.	Area, S sq. ft.	Aspect ratio, b^2/S	Taper ratio c_t/c_r
[a] A	19.0	3.36	0.745	0.25
[a] B	22.0	3.36	1.0	0.25
C	43.9	13.40	1.0	0.25
D	53.8	20.15	1.0	0.25
E	62.1	26.80	1.0	0.25
F	63.0	13.40	2.0	0

[a] Dimensions specified by contractor.

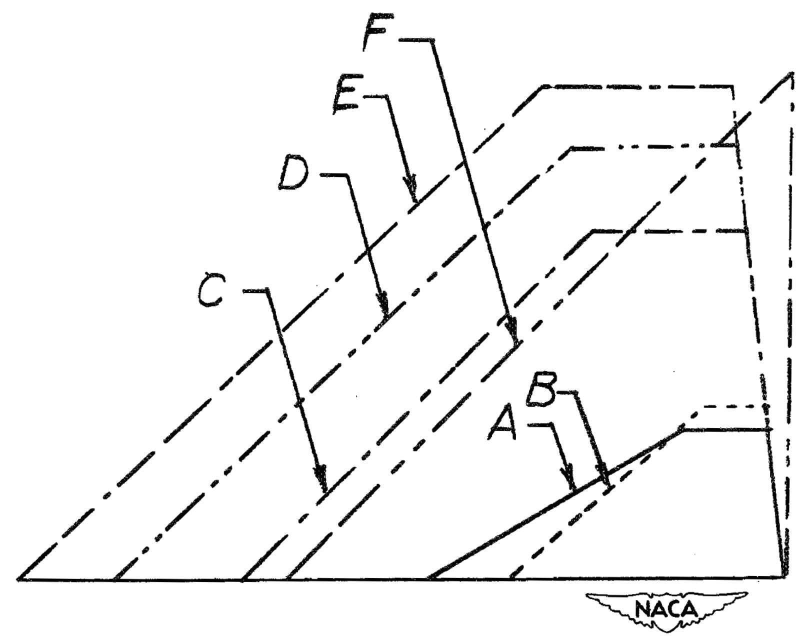

Figure 3.- Relative sizes and full-scale dimensions of fins tested on the $\frac{1}{23}$-scale model of the jettisonable nose section of the X-3 airplane.

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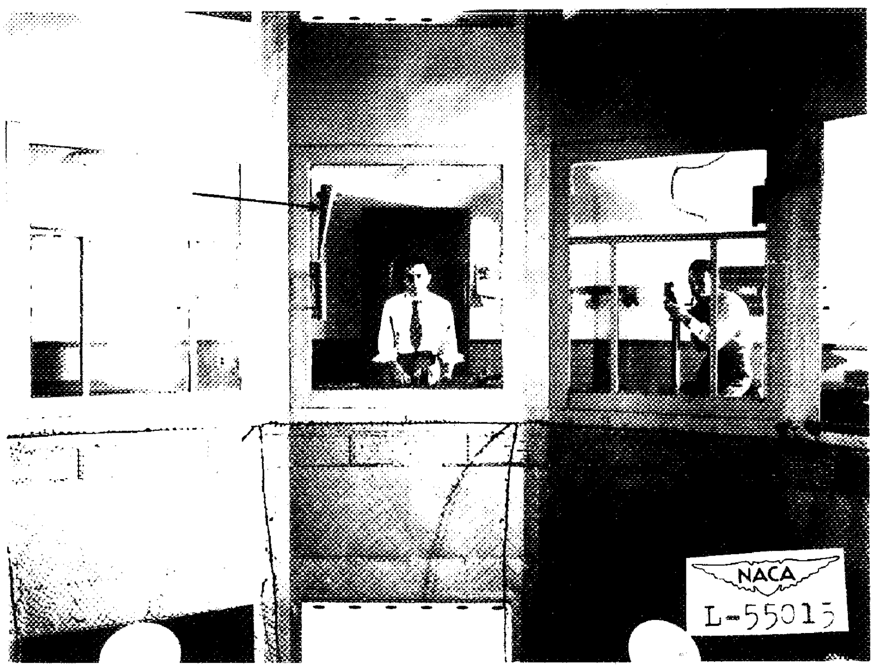

Figure 4.- Photograph showing the test section of the Langley 20-foot free-spinning tunnel, and the $\frac{1}{23}$-scale model of the jettisonable nose of the X-3 airplane being tested. Arrow indicates model.

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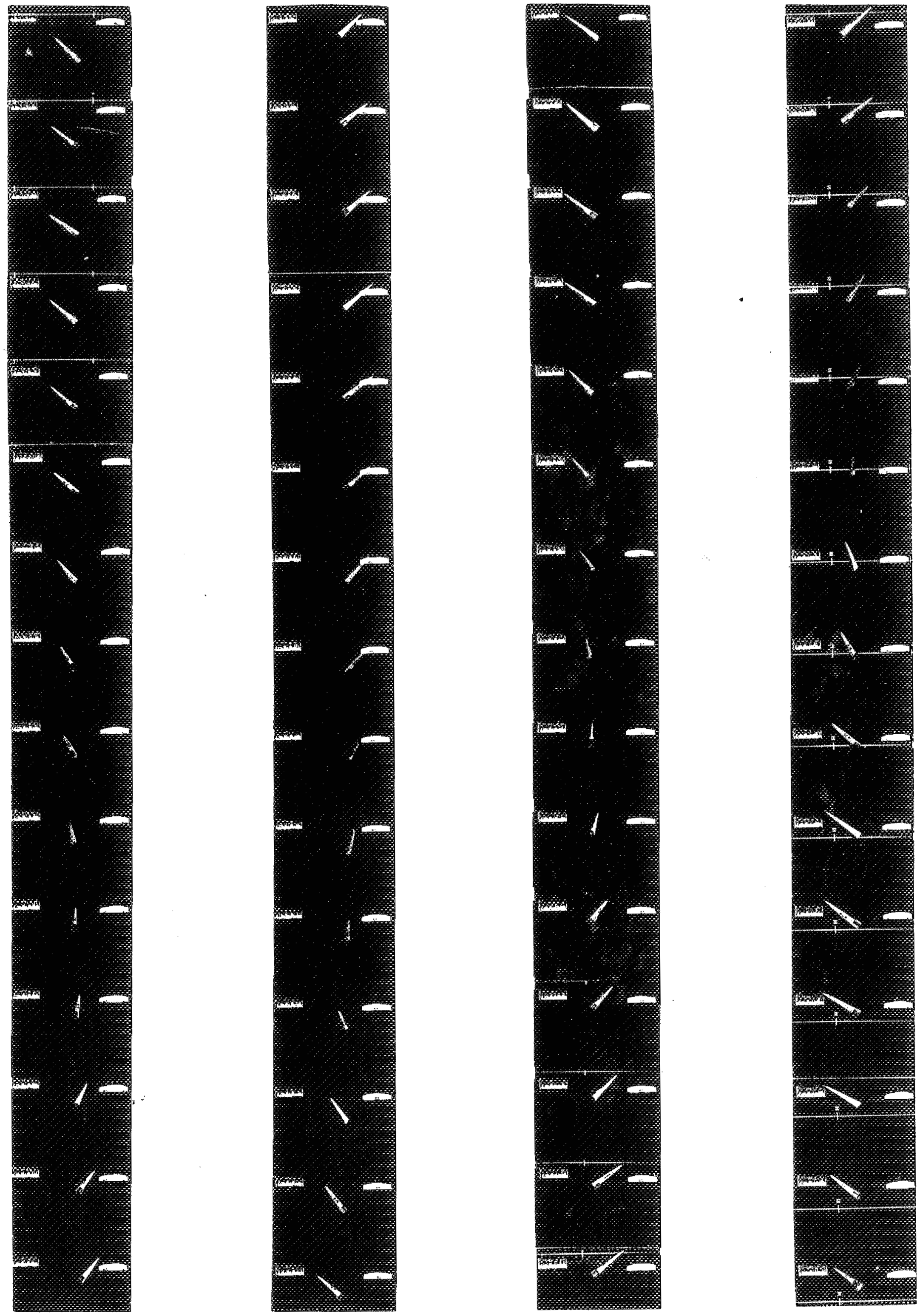

Figure 5.- Motion-picture strips of the $\frac{1}{23}$-scale model of the jettisonable nose section of the X-3 airplane tested in the Langley 20-foot free-spinning tunnel. Original center-of-gravity position, no fins installed. Model shown in equilibrium condition. Camera speed, 32 frames per second.

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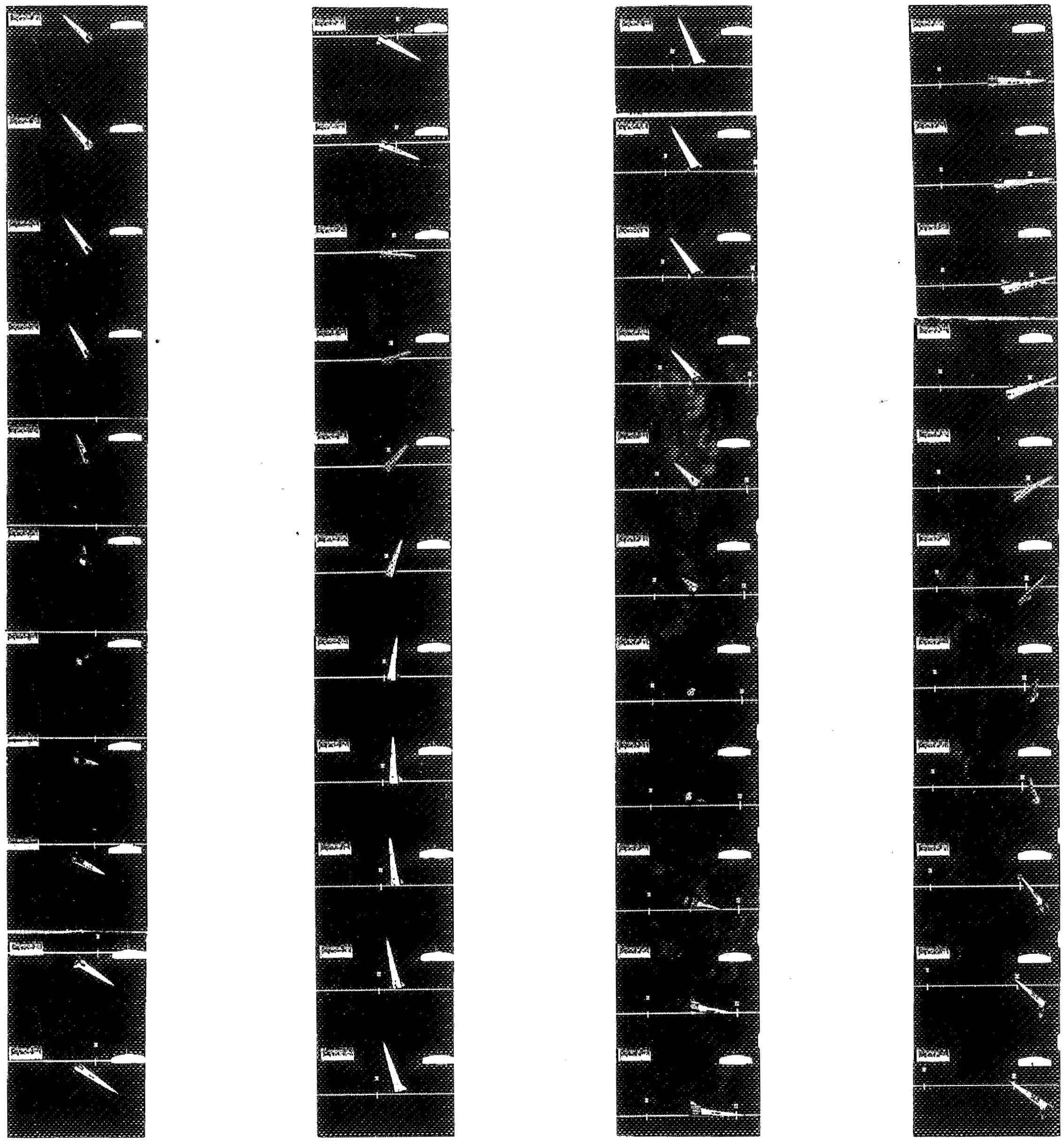

Figure 6.- Motion-picture strips of the $\frac{1}{23}$-scale model of the jettisonable nose section of the X-3 airplane tested in the Langley 20-foot free-spinning tunnel. Original center-of-gravity position, fins B installed. Model shown damping an applied rotation about its normal axis and starting to roll about its longitudinal axis. Camera speed, 32 frames per second.

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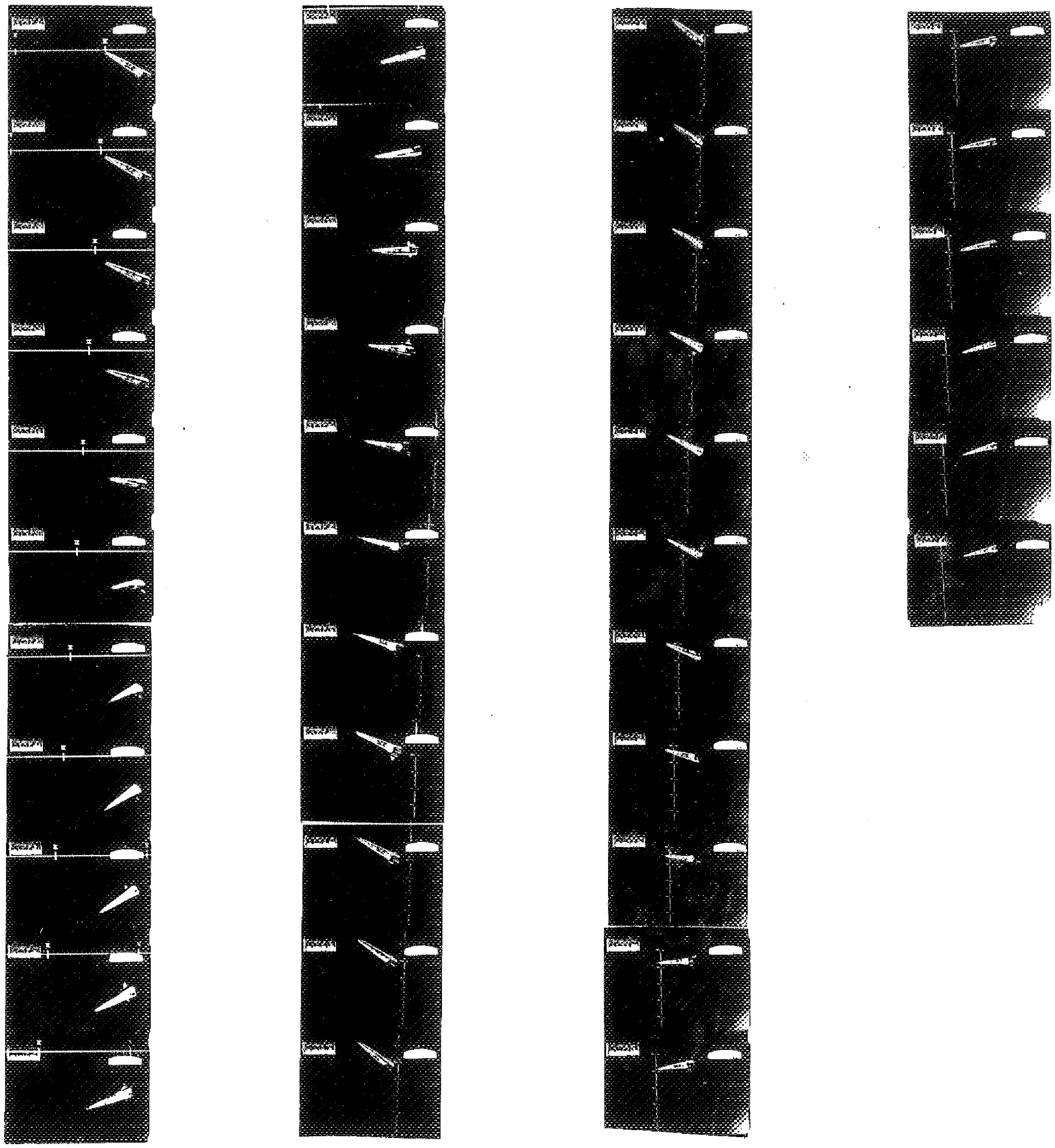

Figure 6.- Concluded.

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ABSTRACT

The stability of the jettisonable nose section of the X-3 airplane has been investigated at low speeds in the Langley 20-foot free-spinning tunnel. The model descended with its front end 36° above the horizontal and rotated about a vertical wind axis while rolling about its longitudinal body axis. Stable front-down descent was obtained when suitable stabilizing fins were installed and the center of gravity was moved forward.