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RESEARCH MEMORANDUM

for the

U. S. Air Force

DYNAMIC INVESTIGATION OF RELEASE CHARACTERISTICS OF A STREAMLINED INTERNAL STORE FROM A SIMULATED BOMB BAY OF THE REPUBLIC F-105 AIRPLANE AT MACH NUMBERS OF 0.8, 1.4, AND 1.98

COORD NO. AF-222

By John B. Lee

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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SUMMARY

An investigation has been conducted in the 27- by 27-inch preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va., of the release characteristics of a dynamically scaled streamlined-type internally carried store from a simulated bomb bay at Mach numbers M_o of 0.8, 1.4, and 1.98. A 1/17-scale model of the Republic F-105 half-fuselage and bomb-bay configuration was used with a streamlined store shape of a fineness ratio of 6.00. Simulated altitudes were 3,400 feet at $M_o = 0.8$, 3,400, and 29,000 feet at $M_o = 1.4$, and 29,000 feet at $M_o = 1.98$.

At supersonic speeds, high pitching moments are induced on the store in the vicinity of the bomb bay at high dynamic pressures. Successful ejections could not be made with the original configuration at supersonic speeds at near sea-level conditions. The pitching moments caused by unsymmetrical pressures on the store in a disturbed flow field were overcome by replacing the high-aspect-ratio fin with a low-aspect-ratio fin that had a 30-percent area increase which was less subject to aeroelastic effects. Release characteristics of the store were improved by orienting the fins so that they were in a more uniform flow field at the point of store release. The store pitching moments were shown to be reduced by increasing the simulated altitude. Favorable ejections were made at subsonic speeds at near sea-level conditions.

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INTRODUCTION

The problem of obtaining successful store releases at supersonic speeds is, at present, of primary concern. Primarily, the store release must be accomplished in a manner such that the store does not strike the airplane. In addition, it is desired that pitch and yaw oscillations of the store be minimized for consistent trajectories and in order to achieve low aerodynamic loadings on the store. The results of store-release tests at supersonic speeds by use of free-fall drops shown in reference 1 indicate that serious troubles may be encountered.

At the request of the Wright Air Development Center, U. S. Air Force, an investigation was made to determine the ejection characteristics of an internally carried streamlined-type store from the fuselage of the Republic F-105 airplane at an ejection velocity of 30 feet per second. It was, of course, desirable to determine if satisfactory ejection characteristics could be obtained under these conditions.

In order to carry this store in the bomb bay of the F-105, the fins have to be folded on the prototype and opened after the store is ejected from the bomb bay. One of the purposes of these tests was to obtain the time allowed to open the stabilizing fins after the store leaves the bomb bay in order to stabilize it before adverse pitch angles and pitch accelerations were reached.

This investigation was made by using 1/17-scale models in the 27- by 27-inch preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va., (ref. 2). The dynamically scaled stores simulated altitudes of 3,400 feet at a Mach number M_o of 0.8, 3,400 and 29,000 feet at $M_o = 1.4$, and 29,000 feet at $M_o = 1.98$ at Reynolds numbers from 5.69×10^6 to 14.63×10^6 per foot. The investigation was of an exploratory nature to determine what interference effects might be involved and to ascertain, in some cases, what modifications might be made to obtain acceptable releases.

SYMBOLS

C_D drag coefficient, $\frac{\text{Drag}}{q_oS}$

C_p static-pressure coefficient, $\frac{p_s - p_o}{q_o}$

65A51-17

h_p	simulated altitude, ft
i_o	store incidence angle at start of ejection stroke, deg
i_t	store-fin incidence angle in pitch plane, deg
I_Y	moment of inertia of store in pitch plane, $lb\text{-}in.^2$
l	store length, in.
L	characteristic length, in.
m	mass
M_o	free-stream Mach number
q_o	free-stream dynamic pressure, lb/sq ft
P	pitching period, milliseconds
p	static pressure, lb/sq ft
p_s	bomb-bay static pressure, lb/sq ft
p_o	free-stream static pressure, lb/sq ft
S	store frontal area, sq in.
t	time, milliseconds
W	store weight, lb
x/l	horizontal distance in terms of store length from store-release point
z/l	vertical distance in terms of store length from store-release point
$\dot{z}_o$	store-ejection velocity, ft/sec
ρ	air density, slugs/cu ft
d	store density, slugs/cu ft

α_f angle of attack of fuselage, deg

θ_s store pitch angle in reference to undisturbed free-stream direction, deg

Subscripts:

m model

p prototype

MODELS AND APPARATUS

Stores

The basic store body and its ordinates are shown in figure 1. The basic stabilizing fin used was a high-aspect-ratio, sweptback fin. The closed and open positions of the fins on the store are shown in figures 2(a) and (b), respectively. Figure 2(c) shows the location of a 30 percent larger low-aspect-ratio fin which was used as a modification to the standard arrangement. The dimensions of the high-aspect-ratio and low-aspect-ratio fins are shown in figure 3. A body modification in the form of a two-dimensional-type nose is shown in figure 4(a). In another modification, the nose of a store was blunted by cutting off 0.9 inch, as shown in figure 4(b).

Photographs of the 1/17-scale model of the 1,700-pound streamlined store are shown in figure 5. Figure 5(a) is a photograph of the store with high-aspect-ratio fins closed and the pitch-plane fins at an angle of incidence of 4°. Figure 5(b) shows the fins in their open position, and figure 5(c) is a photograph of the store modified by the substitution of the low-aspect-ratio fins in place of the regular fins.

In order to scale properly the weights and inertias to simulate a 29,000-foot altitude, the body was made of mahogany with tungsten cores and steel fins. For a 3,400-foot altitude simulation, the body was made of balsa with lead and steel cores and magnesium fins. The method of simulation used is described in the appendix.

Fuselage and Bomb Bay

A 1/17-scale model of the lower half of the Republic F-105 fuselage and bomb bay was used for the tests. The model fuselage was a right circular cylinder with a streamlined nose (fig. 6). The inside walls of the bomb bay were closely shaped to the contour of the store; and with the store in place, there was very little excess area. The top of the bomb bay was formed with trusses or baffles that closely outlined the store. The one-half fuselage and bomb-bay configuration without a wing was attached to the top plate of the nozzle and an extension of the top plate. Figure 6 is a photograph of the fuselage and bomb-bay configuration mounted in the tunnel. Figure 6(a) shows a closeup of the bomb bay empty, figure 6(b) shows a bomb bay with the model in its stored position with fins closed, and figure 6(c) shows the model with fins open in the release position. In order to house the model with its fins open, for these tests, the solid plates at the rear end of the bomb bay were replaced by slotted plates. (See fig. 6(c).)

A sketch of the store in the bomb bay at different incidence angles is shown in figure 7. The length of the ejection stroke was kept the same in all cases ($z/l = 0.164$ or 30-inch full scale). In order to provide for changes in store incidence angles to -4° and -6°, the position of the tail had to be kept the same. As a result, the release point of the center-of-gravity station was extended by $z/l = 0.046$ and 0.07, respectively (figs. 7(b) and (c)). Figure 7(a) shows the location of static-pressure orifices on the bomb-bay side wall, except for orifice 5 which is on the bomb-bay center line.

Ejection Cylinder

Store ejection was accomplished through the use of an ejection cylinder. The ejection cylinder was mounted on the tunnel end support directly above the bomb-bay center line. During the ejection stroke, the rotational motion of the store was prevented by a sway brace which held the store firmly until the release point was reached. The ejection force was applied through the center of gravity of the store. A photograph of an exploded view of the ejection cylinder with its sway braces is shown in figure 8. The ejection device operates as follows: A predetermined pressure is applied to the cylinder to obtain the desired ejection velocity. The solenoid valve is actuated by an electrical impulse that pulls the rod-assembly release pin. The model sway brace is pinned to the rod assembly. The model is held firmly against the sway braces by a small pin in the top of the store that is locked into the rod assembly by two ball bearings (fig. 8(b)). At the bottom of the ejection stroke, the rod assembly is unlocked by the store-release cam, thus releasing the ball bearings from the store pin. The store is then free to move away from the sway brace which has stopped.

The sway braces were interchangeable to give preset incidence angles of 0°, -4°, and -6°. Test results show, however, that the actual release incidence angle changed because of the high aerodynamic loads on the store as it was guided into the airstream. The actual incidence angle of the store at release may be obtained from zero time on the store data curves.

Preflight Jet

All tests were made in the 27- by 27-inch preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va., (ref. 2) in which the stagnation pressures and temperatures could be varied. The Mach number of the test was changed by use of interchangeable nozzle blocks. The test setup is shown in figure 9.

TESTS

Dynamic Similarity

For dynamic testing, exact simulation of prototype conditions is desirable. The usual procedure is to match the similarity parameters that have the greatest influence on test data. Corrections may then be attempted to account for the effect of those parameters which are not duplicated; or, if it can be shown that the probable differences are small, they may be neglected.

The Mach numbers for the model tests were the same as those for the airplane. Dynamic scaling was obtained by (1) maintaining the ratio of store density to dynamic pressure the same for the model as for the prototype store, and by (2) maintaining the mass distribution of the store model the same as that in the store prototype. This scaling results in the following scaling equations:

$$\left(\frac{\rho l^3}{m}\right)_m = \left(\frac{\rho l^3}{m}\right)_p$$

and

$$\left(\frac{\rho l^5}{I}\right)_m = \left(\frac{\rho l^5}{I}\right)_p$$

The basis for this similarity is enlarged upon in the appendix and in reference 3.

Since the acceleration due to gravity cannot be altered, the vertical acceleration due to gravity for the model tests is too small for dynamic similarity by the scale factor. The effect of not properly simulating gravity has been shown in reference 3. Since these tests are made with an ejection velocity of 30 feet per second, the effect of gravity on the vertical motion of the model is small.

Except as effected by a second-order vertical-position error as noted, all aerodynamic forces and moments, the resulting pitching angles and vertical and horizontal displacements due to aerodynamic forces, and all damping effects are faithfully represented.

Test Methods

The store was held inside the bomb bay until the tunnel pressure was adjusted to give sea-level ambient conditions. The solenoid valve was energized by an electrical impulse and the solenoid actuated the rod-assembly release pin. The ejection cylinder had been pressurized to a predetermined pressure, depending on the store weight to give the desired ejection velocity at the end of the stroke. The ejection stroke was 1.76 inches long (simulating 30-inch full scale).

The electrical impulse that released the model by means of the solenoid valve was synchronized with the shutter of an 8 by 10 camera and a bank of 20 Strobolights. The camera shutter was set at 1/20 of a second and the bank of lights were fired in sequence at 2-millisecond intervals by a 1,000-cycle timer. The picture obtained is thus a Strobolight picture of a scaled time trajectory on one sheet of 8 by 10 film. The store pitch angle and trajectory were read directly from the Strobolight picture.

A summary of the estimated maximum probable errors for the tests of the store models is presented in the following table:

x/l	±0.004
z/l	±0.004
θ_s, deg	±0.5
p, lb/sq ft	±0.01
M_o	±0.01
$\dot{z}_o$, ft/sec	±1.00
C_D	±0.005

RESULTS AND DISCUSSION

Ejection Photographs

Table I lists the tests and the pertinent data of each test. Figures 10, 11, and 12 are Strobolight pictures of tests at $M_o = 1.4$, 1.98, and 0.8, respectively.

Figure 10 shows attempts to eject the store at $M_o = 1.4$ and simulating a 3,400-foot altitude. As the store is ejected it has a nose-up tendency and obtains lift as the pitch angle increases, and it then flies back into the bomb bay. Figure 10 also shows the fins curling as the store pitch angle increases. As listed in table I, modifications were used to attempt to eliminate these conditions. These modifications will be discussed later. Additional modifications were attempted which included chamfering the rear end of the bomb bay, ducting the rear end of the bomb bay, and using a spoiler plate in front of the bomb bay. Since these modifications did not improve the release characteristics of the store, they are not reported and no further discussion will be made on them.

Data Plots

Plots of the store pitch angle θ_s against time in milliseconds and against the vertical distance in terms of the store length are shown in figures 13 to 19. The release point of the store is zero time. The store trajectory is also shown in terms of the store length. The point close to impact is darkened if the store strikes the bomb bay or fuselage.

Ejections at $M_o = 1.4$

Attempts to eject the store at $M_o = 1.4$ at a simulated 4,000-foot altitude were not successful. The models pitch nose up and strike the bomb bay within 6 to 9 milliseconds after release. In figure 13 it can be seen that the fins' open and closed models have essentially the same pitch amplitudes and trajectories. An analytical estimate of the effects of flexibility on effectiveness of the high-aspect-ratio fins showed the fins to be approximately 75-percent effective for the $M_o = 1.4$ test conditions (q_o = 2,900 lb/sq ft). It can also be noted from some of the Strobolight pictures that the fins curl because of aeroelastic effects. By increasing the simulated altitude to 29,000 feet with the fins open, an ejection was obtained that reached a maximum pitch amplitude of 20° and appeared to stabilize.

In figure 13, a comparison of the tests with the fins open and fins closed, at a simulated 29,000-foot altitude, shows that the two stores follow approximately the same pitch amplitudes and trajectories for the first few milliseconds. It, thus, appears that, if the fins are opened within the first 4 milliseconds after release (0.068 second full scale), the store should closely follow the ejection with the fins open.

Many modifications were tried in order to obtain successful ejections at $M_o = 1.4$ at a simulated 4,000-foot altitude. Figure 14 shows the results of attempts to overcome the high pitching moment of the store by ejecting the store at a negative incidence angle. In test 7 the store reached a maximum pitch angle $\theta_s = 21^\circ$ and attempted to stabilize, but the store had obtained enough upward motion because of lift that the tail fins struck the model fuselage.

It is considered probable that the release characteristics could be improved by imparting a negative pitching motion to the store during its ejection stroke. Thus, the store would have an angular momentum to combat the upward pitching forces during emergence from the cavity. Such tests, however, were beyond the capacity of the model-ejection mechanism.

All tests indicate that the store had a large nose-up pitching moment at the time of release. Tests were made in the form of body changes to check the effects of dynamic pressures on the nose of the store (fig. 15). Blunting the nose did not appear to improve the release characteristics of the store (test 8). The nose-up pitching moment at release appeared to be eliminated by a two-dimensional type of nose (test 9). The store was actually ejected at a larger negative incidence angle of -6° than the preset incidence angle ($i_o = -4^\circ$), whereas the unmodified nose was released at 0°. The model was not stable laterally, however, and proceeded to roll and yaw after release (fig. 10(i)).

Results of tests to determine the effect of changing fin position at release point are shown in figure 16. With the fins rotated 180°, the store started to recover at a pitch angle of 14°. Since the vertical fin had been eliminated, the store then began to yaw and roll. By extending the release point by $z/l = 0.07$, the store pitched to a maximum pitch angle of 18° and then recovered. The store, however, had obtained enough upward motion because of lift to strike the bomb bay. These stores which attempted to stabilize are compared with an ejection with the fins in the standard position which is shown to continue to pitch nose-up. These tests show the importance of placing the fins farther away from the bomb bay in a more uniform flow field where the fins will be more effective. A comparison of these ejections with the negative-incidence ejections in figure 14 shows that the negative-incidence ejections obtain greater pitch amplitudes.

Extending the release point of the store, however, would probably penalize the airplane in weight because of the added strength needed in the ejection mechanism and rod.

Various photographs of the tests showed the standard fins, made from magnesium, curling because of high loads, thus resulting in large decrease in effectiveness. Figure 17 shows the effect of using stiffer fins. The magnesium fins were replaced by aluminum fins for test 12; this resulted in a weight increase (changing the simulated altitude to 7,000 feet) and an inertia increase from 1.43 to 2.04. The store center-of-gravity position was changed from 35 percent to a 38.4 percent of the store length. This ejection showed considerable improvement over an ejection using the standard magnesium fin. The resulting ejection compares favorably with the negative-incidence ejection of 4° (fig. 14).

A low-aspect-ratio fin with a 30-percent increase in fin area was used to increase the static stability of the store and to obtain a fin subjected to a lesser extent to aeroelastic effects (test 14). The center-of-gravity position of this store was 36.8 percent. The results of this ejection are compared with the high-aspect-ratio fins ejected under similar conditions; that is, in both tests the release point was extended by $z/l = 0.07$. This was the only successful release at 3,400 feet at $M_o = 1.4$. The store obtained a pitch angle of 12° before recovering.

A shadowgraph at $M_o = 1.4$ of the flow field around the ejection rod and sway brace is shown in figure 20. The interference caused by the sway brace may have a large effect on the store pitch amplitudes. Model tests should duplicate all of the pertinent details of the full-scale bomb bay as pointed out in reference 3. Figure 21 shows test 5 with the store passing through this flow field. It is apparent that the after-portion of the store was in the vicinity of the strong shocks emanating from the sway brace throughout its trajectory.

Ejections at $M_o = 1.98$

Favorable ejections were obtained at $M_o = 1.98$ at a simulated altitude of 29,000 feet with fuselage angles of attack of 0° and 3° as shown in figure 18. A maximum pitch angle of $\theta_s = -13^{\circ}$ was obtained at a fuselage angle of attack $\alpha_f = 3^{\circ}$ and a preset store incidence angle of $i_o = 0^{\circ}$ in test 15. Figure 18 shows that the store was actually released at 6°. A repeat ejection showed excellent repeatability. With the fuselage angle of attack of $\alpha_f = 0^{\circ}$ and $i_o = -4^{\circ}$ in test 17, the store was released at approximately $\theta_s = 0^{\circ}$ and stabilized to less than a 1° pitch amplitude in 1 cycle. In test 18, an ejection was made at $\alpha_f = 0^{\circ}$, $i_o = 0^{\circ}$, and with the fins rotated 180°. Since the vertical fin was removed, the store yawed. This ejection compared favorably with the negative-incidence ejection, as was also shown in the $M_o = 1.4$ tests.

Ejections at Subsonic Speeds

Successful ejections were made at subsonic speeds ($M_o = 0.8$) as shown in figures 12 and 19. The fins should be opened in less than 4 milliseconds after release to obtain a trajectory similiar to the ejections with the fins open. Comparison of these tests with the previously shown supersonic tests can be taken as a measure of the increased difficulty that can be expected as the operational speed of bombing aircraft becomes supersonic.

Coefficients

Pressure coefficients.- Static-pressure measurements were taken in the bomb bay with the store in place and with the bomb bay empty (fig. 17(a)). Values obtained are shown in figure 22. Stations 1, 2, 3, and 4 were on the bomb-bay wall and station 5 was on the bomb-bay center line. Station 5 was reading a partial impact pressure.

Drag coefficients.- A drag coefficient was computed for the store in the vicinity of the bomb bay from the store's horizontal acceleration. The drag coefficient was based on undisturbed free-stream q_o and store frontal area. This drag coefficient was obtained to give an indication of drag loads on the store in the vicinity of the bomb bay.

At $M_o = 1.40$ and $\alpha_f = 0^\circ$, a maximum drag coefficient of 0.67 was obtained at a store pitch angle of approximately 0°. In reference 4, a maximum drag coefficient of 0.405 was obtained at $M_o = 1.2$ from free-flight models of the Douglas Aircraft Co., Inc., (DAC) 10,000-pound store ($l/d = 5.10$). A large increase in drag coefficient, due to interference drag of a store in the vicinity of the bomb bay, is also reported in reference 5. At $M_o = 1.98$, drag coefficients of 0.75 and 0.54 were obtained at $\alpha_f = 3^\circ$ and 0°, respectively. The drag coefficient decreased to 0.35 in an area of the tunnel where it is believed that the air flow was not affected by the fuselage.

At $M_o = 0.8$, a drag coefficient of 0.11 was obtained near release and also out in the airstream. This drag coefficient compares favorably with the DAC store shape ($l/d = 5.10$) in reference 4. Interference drag was expected to be at a minimum at subsonic speeds.

CONCLUSIONS

As a result of the investigation of store ejections at Mach numbers of 0.8, 1.4, and 1.98, the following conclusions are indicated:

1. At low altitudes and supersonic speeds, the basic streamline store tested obtained large pitching moments in the vicinity of the bomb bay and struck the bomb bay and fuselage soon after release.

2. In order to overcome the pitching moments caused by unsymmetrical pressures on the store in a disturbed flow field, a low-aspect-ratio fin with a 30-percent area increase that is less subject to aeroelastic effects can be used to obtain successful releases at low altitudes.

3. Release characteristics of the store are improved by orienting the fins so that they are in a more uniform flow field at the point of store release.

4. An increase in altitude (or decrease in dynamic pressure) is beneficial to the release characteristics of the store at supersonic speeds.

5. Favorable ejections were made at high subsonic speeds at near sea-level conditions.

6. The fins should be opened in 4 milliseconds after release for both subsonic and supersonic speeds to stabilize the store.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 16, 1956.

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APPENDIX

SIMILARITY RELATIONSHIP

In order to discuss properly the effects of scale on the store motion, some simplified equations are first derived relating to the translational and rotary motion of the store. Translational motion resulting from drag forces and rotary motion in pitch are determined only. However, the other translational and rotary motions will follow the same relationships.

The analysis is made with the assumption that the aerodynamic coefficients do not vary with scale (no Reynolds number effect). In addition, the free-stream Mach number is the same for model and full scale. With those factors held constant, the variables defining the model motion can be reduced to three and are

d	store density
q	dynamic pressure
L	characteristic length

The characteristic length is an arbitrary length, such as store diameter, which defines the model scale in relation to the full-size store. Other variables can then be stated in terms of the fundamental variables:

$\bar{c}$	mean aerodynamic chord $(\bar{c} \propto L)$
K	radius of gyration $(K \propto L)$
S	area $\left(S \propto L^2\right)$
p	static pressure $(p \propto \rho T \propto q)$
ρ	air density, $\left(\rho \propto \frac{2q}{TM^2} \propto \frac{q}{T}\right)$
m	mass $\left(m \propto dL^3\right)$
V	velocity $\left(V \propto \sqrt{T}\right)$
I_Y	moment of inertia $\left(I_Y \propto dL^5\right)$

$$I' = \frac{I_Y}{Sq\bar{c}} \propto \frac{dL^5}{L^2 qL} \propto \frac{dL^2}{q} \qquad \left(I' \propto \frac{dL^2}{p}\right)$$

$$m' = \frac{mV}{Sq} \propto \frac{dL^3\sqrt{T}}{L^2 q} \qquad \left(m' \propto \frac{dL\sqrt{T}}{p}\right)$$

The store-motion parameters to be found are listed as

a	translational acceleration from aerodynamic drag forces
t	time required to be accelerated an incremental distance proportional to L by aerodynamic force
ΔV	change in velocity during time t
P	pitching period
$T_{1/2}$	time to damp to one-half amplitude

The relationship existing between the store-motion parameters and the fundamental variables are next derived. For convenience, those relationships which are of fundamental importance are numbered for subsequent identification:

$$a = \frac{C_D Sq}{m} \propto \frac{L^2 q}{dL^3} \propto \frac{q}{dL} \qquad \left(a \propto \frac{p}{dL}\right) \tag{1}$$

$$t^2 = \frac{2L}{a} \propto \frac{2L}{q/dL} \propto \frac{dL^2}{q} \qquad \left(t \propto \sqrt{\frac{d}{p}}\, L\right) \tag{2}$$

$$\Delta V = at \propto \frac{q}{dL}\sqrt{\frac{d}{q}}\, L \propto \sqrt{\frac{q}{d}} \qquad \left(\Delta V \propto \sqrt{\frac{p}{d}}\right) \tag{3}$$

$$P = \frac{2\pi}{\sqrt{\dfrac{57.3 Cm_\alpha}{I'}}} \approx \sqrt{I'} \propto \sqrt{\frac{d}{q}}\, L \qquad \left(P \propto \sqrt{\frac{d}{p}}\, L\right) \tag{4}$$

$$\frac{1}{T_{1/2}} = \frac{57.3}{2\ \ln 2}\,\frac{1}{m'}\left[\left(C_{m_q} + C_{m_{\dot{\alpha}}}\right)\frac{1}{2}\left(\frac{\bar{c}}{K}\right) - C_{L_\alpha}\right] \qquad \text{(see ref. 6)}$$

$$\frac{1}{T_{1/2}} = \frac{1}{m'} - T_{1/2} \propto m' \propto \frac{dL\sqrt{T}}{q} \qquad T_{1/2} \propto \frac{dL\sqrt{T}}{p} \qquad (5)$$

Now it can be seen that, by making the ratio of static pressure to store density p/d constant, the period and the time to accelerate under aerodynamic forces to a characteristic distance L are proportional to L, the characteristic length (eqs.(2) and (4)). If the tunnel temperature can be varied to obtain the simulated-altitude static temperature, time to damp to one-half amplitude also becomes proportional to L (eq.(5)). Thus, if the motion is considered in terms of the position of the store with respect to the mother ship in units of L, these motions will be the same regardless of scale size. In addition, the amount the velocity has changed during the time the model moves an increment of L is independent of scale (eq.(3)). Thus, the translational velocity is always duplicated. The number of cycles required to damp to one-half amplitude will be the same for the model as for the prototype $\left(N = \frac{T_{1/2}}{p} = \frac{L}{L}\right)$.

It can be shown from this that, when the ratio of store density to static pressure is held constant, the model moves a scaled distance in length of time proportional to the scale factor. Thus, the Strobolight pictures obtained from these tests are scale representations with the time between store positions equal to 1/17 full scale.

In order for the vertical translational motion to be correct, the gravitational acceleration required for the model must vary in the same manner as the aerodynamic acceleration. From equation (1) it can be seen that the aerodynamic acceleration is inversely proportional to L. Thus, the proper gravitational acceleration should vary inversely with model size; that is, it becomes larger for the model. However, the error due to not properly simulating gravity becomes smaller as the initial ejection velocity is increased. This effect is enlarged upon in reference 3. An ejection velocity of 30 feet per second was used for the tests in the present report.

With the ratio of the store static pressure to store density constant, the proper scaling parameters become

$$\left(\frac{p}{d}\right)_m = \left(\frac{p}{d}\right)_p$$

Since

$$m = dL^3$$

or

$$d = \frac{m}{L^3}$$

then

$$\left(\frac{pL^3}{m}\right)_m = \left(\frac{pL^3}{d}\right)_p \tag{6}$$

And since

$$I_Y = dL^5$$

or

$$d = \frac{I_Y}{L^5}$$

then

$$\left(\frac{pL^5}{I_Y}\right)_m = \left(\frac{pL^5}{I_Y}\right)_p \tag{7}$$

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TABLE I.- TEST SEQUENCE

Test	Figure	M_o	$\dot{z}_o$, ft/sec	α_f, deg	i_o, deg	Fins	h_p, ft	W, lb	I_Y, lb-in.^{2}	Center-of-gravity station, in.	Center-of-gravity station, percent	Remarks
1	10(a)	1.4	30	0	0	Closed	3,400	0.398	1.398	3.716	34.5	None
2	10(b)	1.4	30	0	0	Closed	3,400	.386	1.430	3.700	34.4	4° tail incidence
3	10(c)	1.4	30	0	0	Open	3,400	.400	1.414	3.711	34.5	None
4	10(d)	1.4	30	0	0	Closed	29,000	1.134	4.220	3.696	34.3	Density check
5	10(e)	1.4	30	0	0	Open	29,000	1.140	3.950	3.686	34.2	Density check
6	10(f)	1.4	30	0	-4	Open	3,400	.389	1.380	3.741	34.8	Incidence change
7	10(g)	1.4	30	0	-6	Open	3,400	.388	1.570	3.730	34.7	Incidence change
8	10(h)	1.4	30	0	-6	Open	3,400	.381	1.440	3.716	34.5	Blunt-nose modification
9	10(i)	1.4	30	0	-4	Open	3,400	.486	1.430	3.700	34.4	Two-dimensional nose
10	10(j)	1.4	30	0	0	Open	3,400	.402	1.410	3.666	34.1	Fins' position rotated 180°
11	10(k)	1.4	30	0	0	Open	3,400	.400	1.418	3.716	34.5	Fin-position release point extended $z/l = 0.07$
12	10(l)	1.4	30	0	0	Open	7,000	.449	2.036	4.130	38.4	Stiffer fins
13	10(m)	1.4	30	0	0	Open	3,400	.428	2.079	3.960	36.8	Low-aspect-ratio fins; 30-percent fin area increase; z/l extended 0.07
14	10(n)	1.4	30	0	0	Open	3,400	.428	2.079	3.960	36.8	Low-aspect-ratio fins (repeat of test 13)
15	11(a, b)	1.98	30	3	0	Open	29,000	1.147	4.260	3.704	34.5	None
16	11(c)	1.98	30	3	0	Open	29,000	1.117	4.092	3.716	34.5	None
17	11(e)	1.98	30	0	-4	Open	29,000	1.140	3.950	3.686	34.2	None
18	11(d)	1.98	30	0	0	Open	29,000	1.130	4.140	3.716	34.5	Fins rotated 180° and top fin removed
19	12(a)	.8	30	0	0	Closed	3,400	.390	1.430	3.710	34.5	None
20	12(b)	.8	20	0	0	Closed	3,400	.391	1.430	3.710	34.5	None
21	12(c)	.8	30	0	0	Open	3,400	.391	1.430	3.710	34.5	None
22	12(d)	.8	30	0	-4	Open	3,400	.391	1.430	3.710	34.5	None

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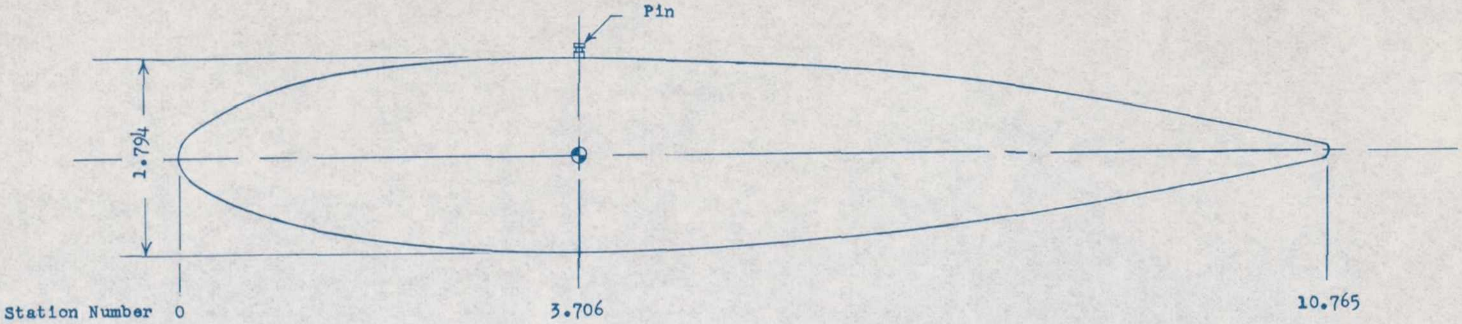
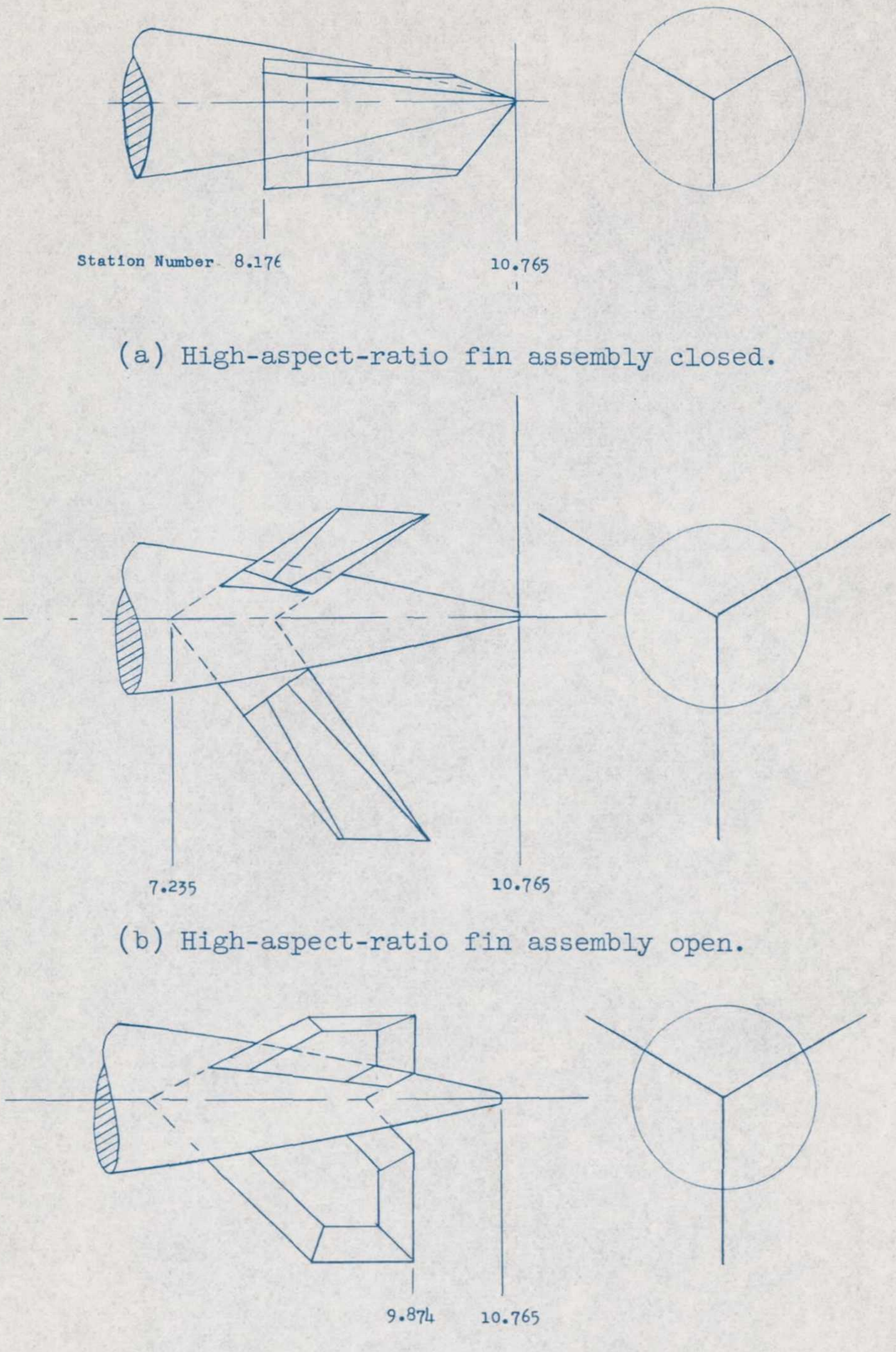


Store Ordinates, inches	
1/17 size	
Station	Radius
.088	.208
.206	.315
.324	.391
.515	.487
.687	.555
.860	.612
1.033	.661
1.206	.704
1.794	.811
2.088	.847
2.382	.874
2.676	.890
2.971	.897
4.559	.897
5.077	.890
5.595	.869
6.113	.835
6.632	.789
7.161	.730
7.670	.654
8.187	.577
8.706	.488
8.941	.444
10.765	0
Leading-edge radius, .248	
Trailing-edge radius, .108	

Figure 1.- A 1/17-scale model of the Republic F-105 streamlined store with body ordinates. $l/d = 6.0$. All dimensions are in inches.

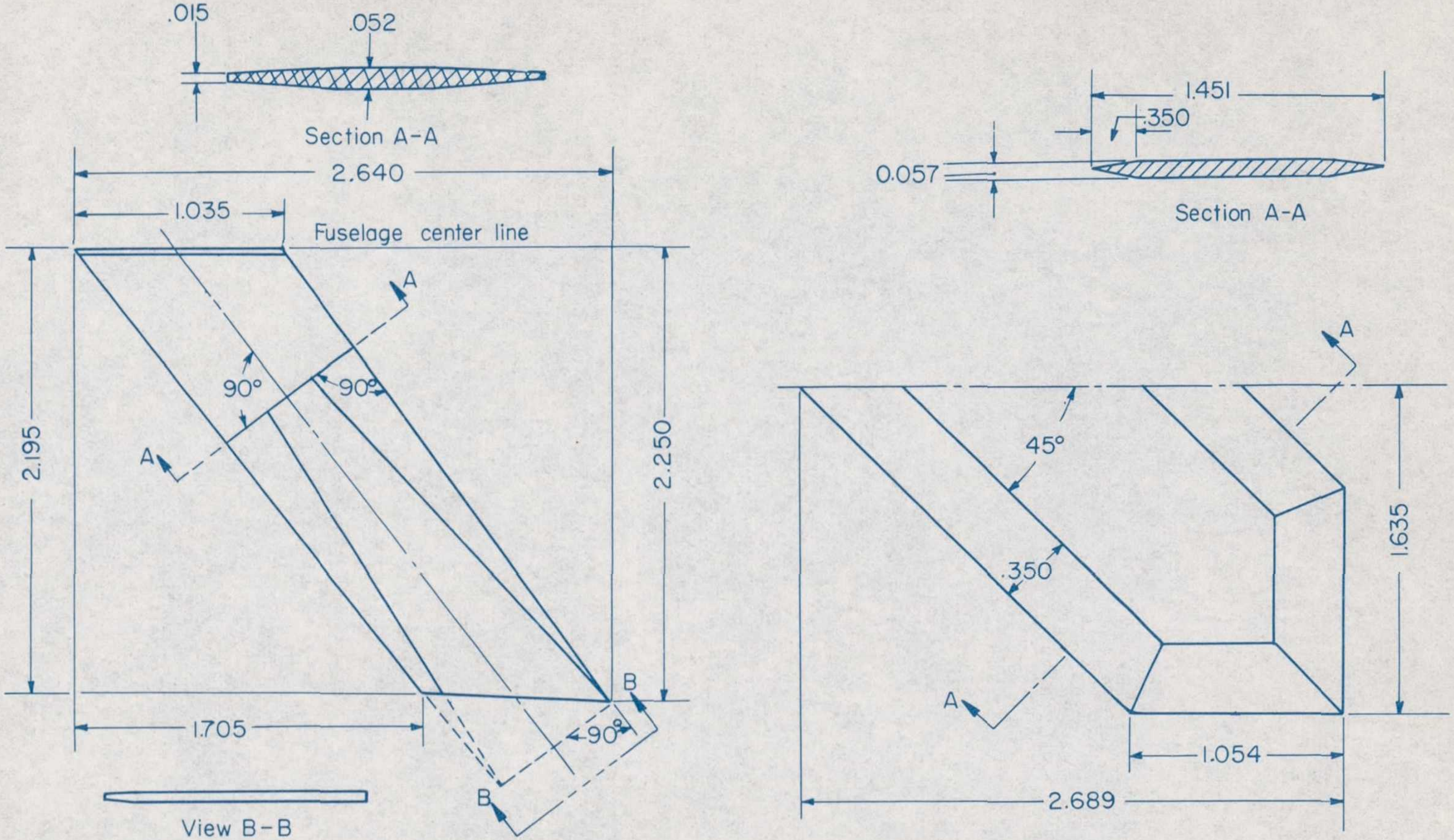


(a) High-aspect-ratio fin assembly closed.

(b) High-aspect-ratio fin assembly open.

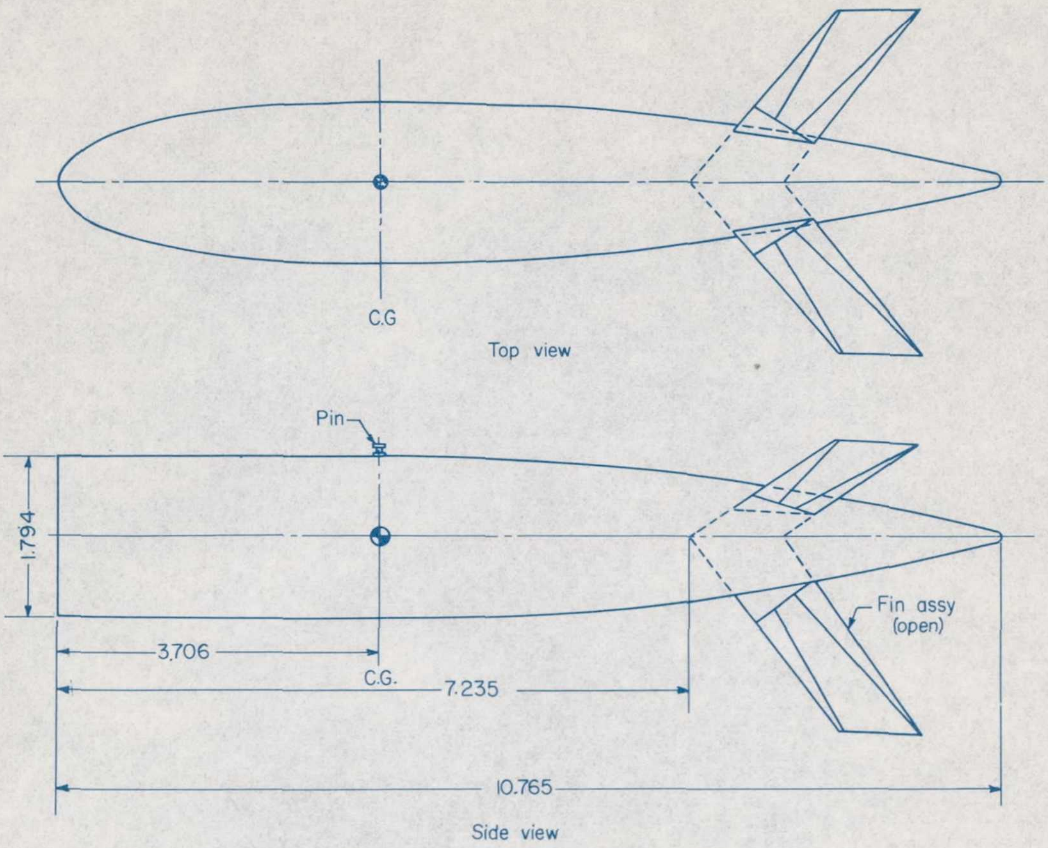
(c) Low-aspect-ratio fin assembly open.

Figure 2.- The Republic F-105 streamlined-store fin assembly. All dimensions are in inches.

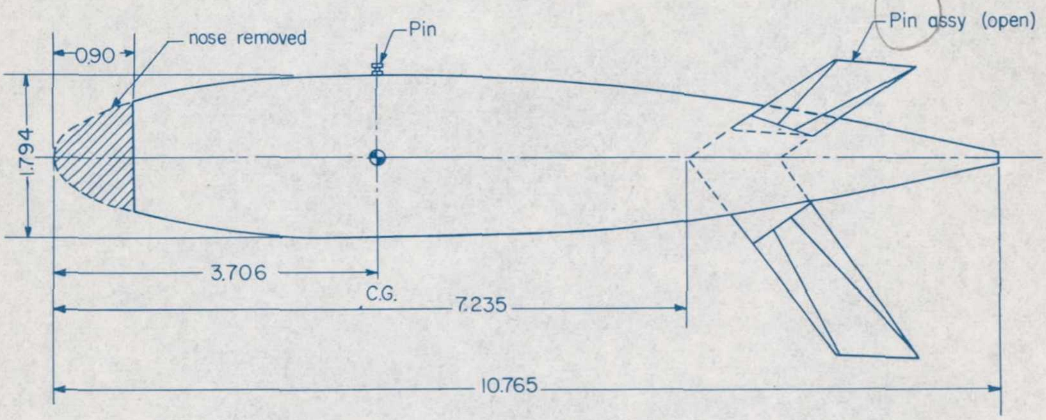


(a) High-aspect-ratio fins. (b) Low-aspect-ratio fins.

Figure 3.- Sketch showing 1/17-scale streamlined-store fin dimensions and designations. All dimensions are in inches.

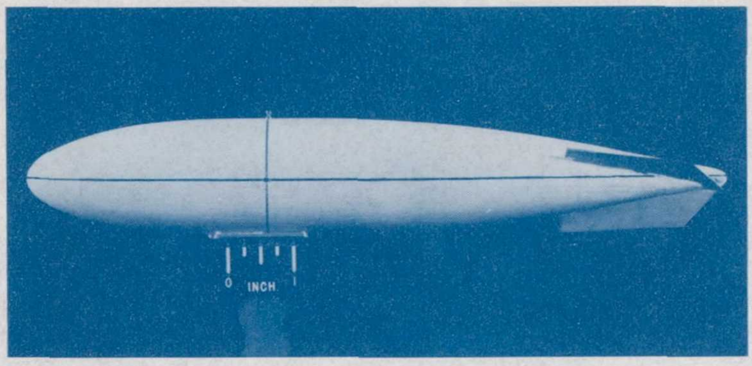


(a) Store with two-dimensional nose.

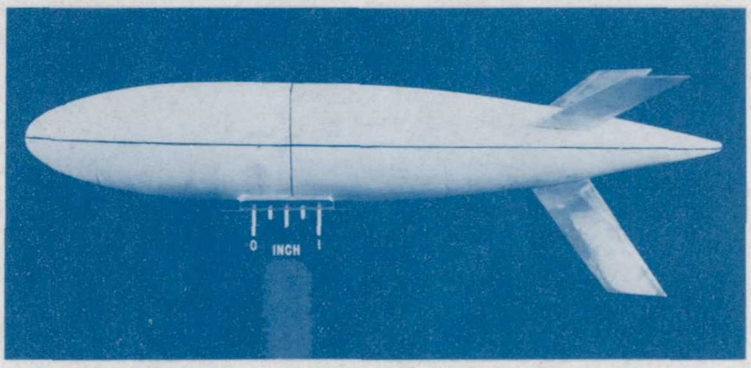


(b) Store with blunt nose.

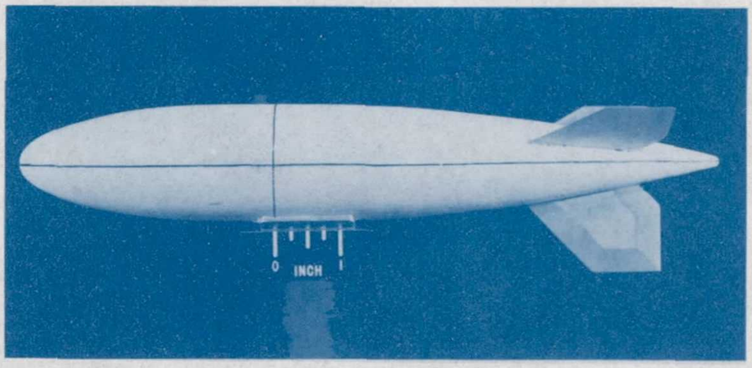
Figure 4.- Nose modifications of 1/17-scale streamlined store. All dimensions are in inches.



(a) High-aspect-ratio fins closed. Tail incidence angle, $i_t = 4^{\circ}$.



(b) High-aspect-ratio fins open.



(c) Low-aspect-ratio fins open. L-93531

Figure 5.- A 1/17-scale model of the 1,700-pound Republic F-105 streamlined store. $l/d = 6.0$.

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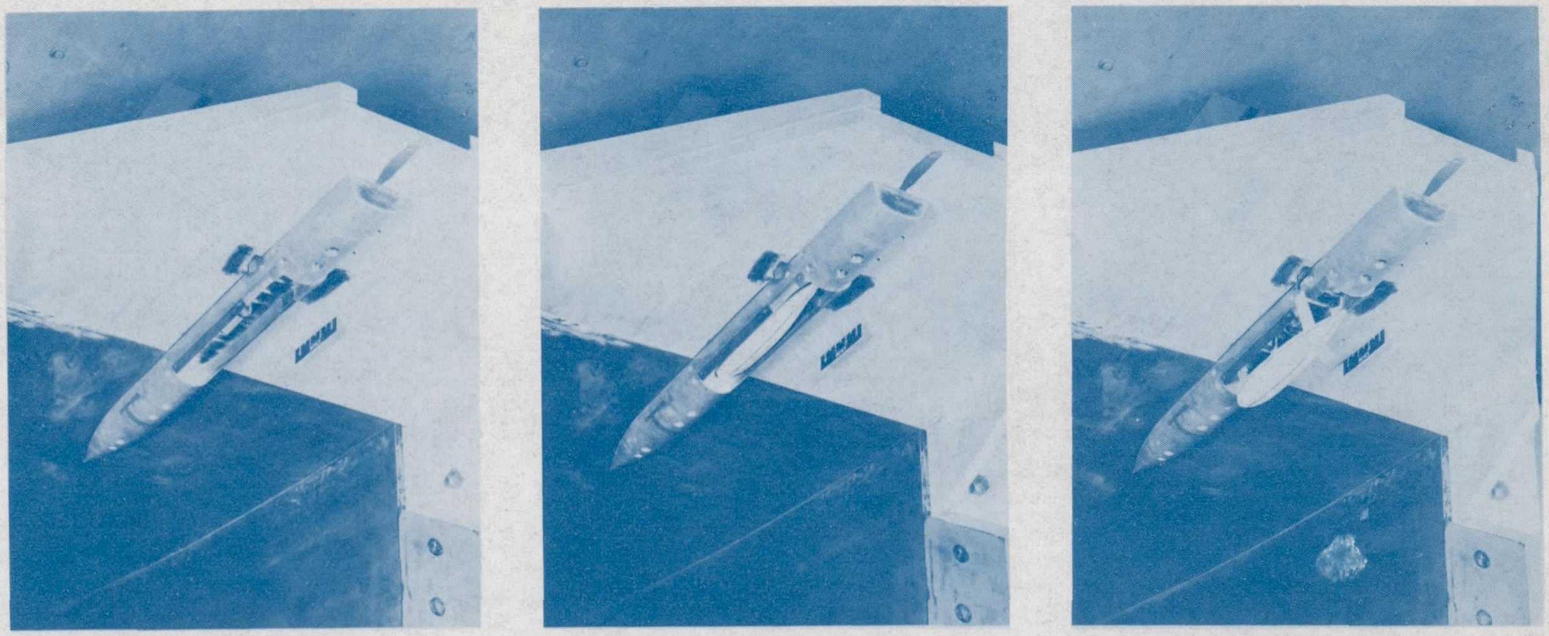

L-93532

(a) Bomb bay empty. (b) Model, with fins closed, in stored position. (c) Model, with fins open, in release position.

Figure 6.- Closeup view of one-half fuselage of the 1/17-scale model of the Republic F-105 bomb bay mounted in the preflight jet.

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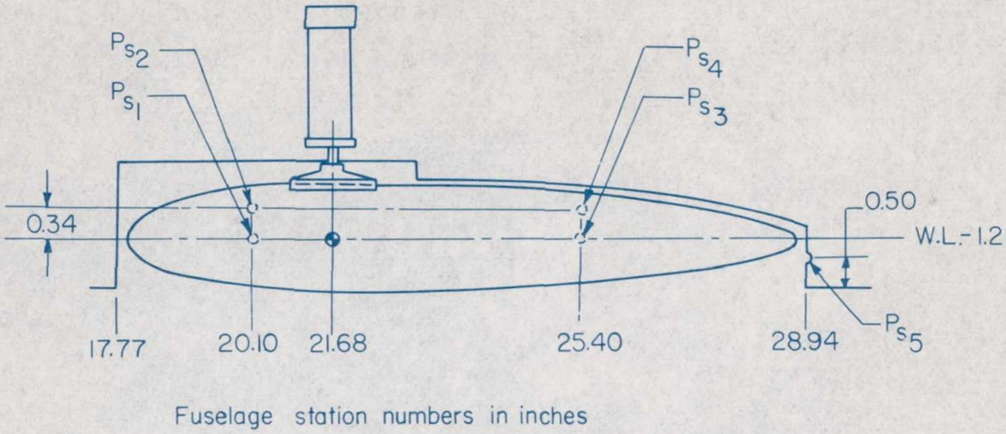
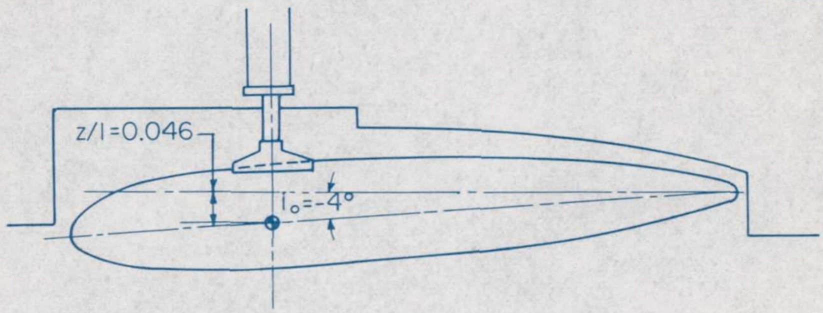
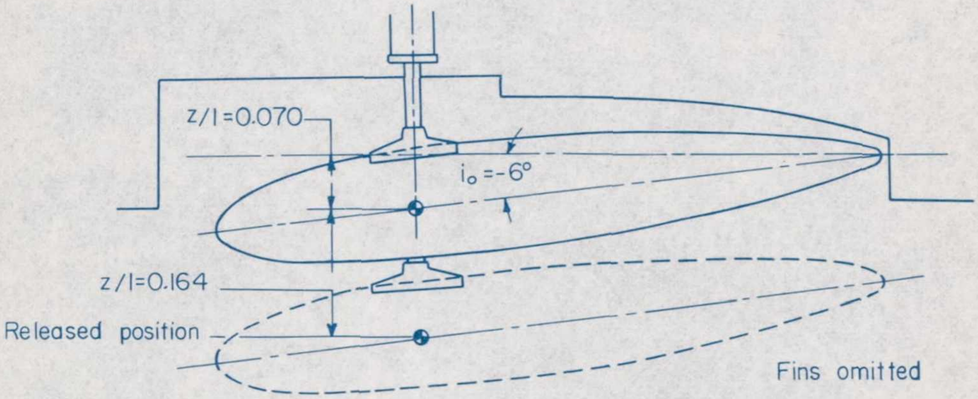


(a) Incidence angle, 0°.



(b) Incidence angle, -4°.



(c) Incidence angle, -6°.

Figure 7.- Sketch of 1/17-scale streamlined store in bomb bay at various incidence angles.

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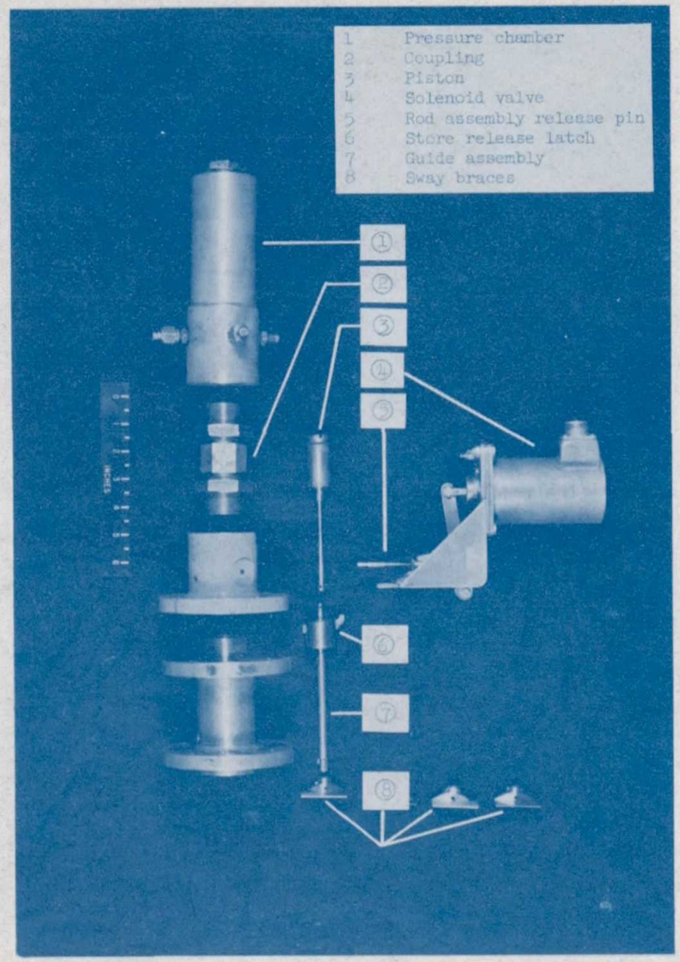
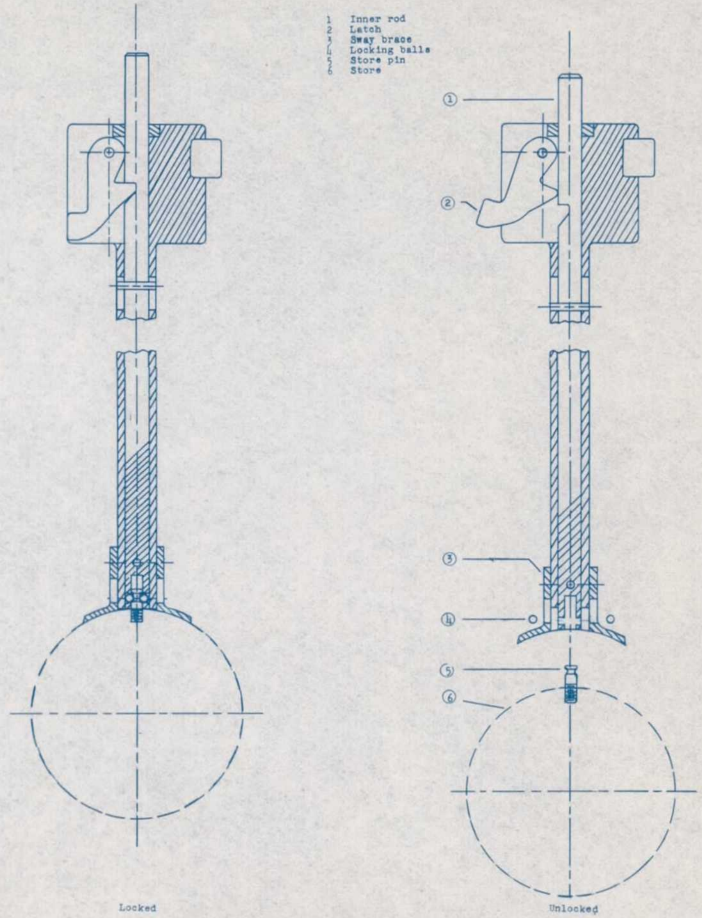


L-89034.1

(a) Exploded view of ejection cylinder with sway braces.



(b) Ejection rod assembly.

Figure 8.- Ejection mechanism.

Figure 8.- Concluded.

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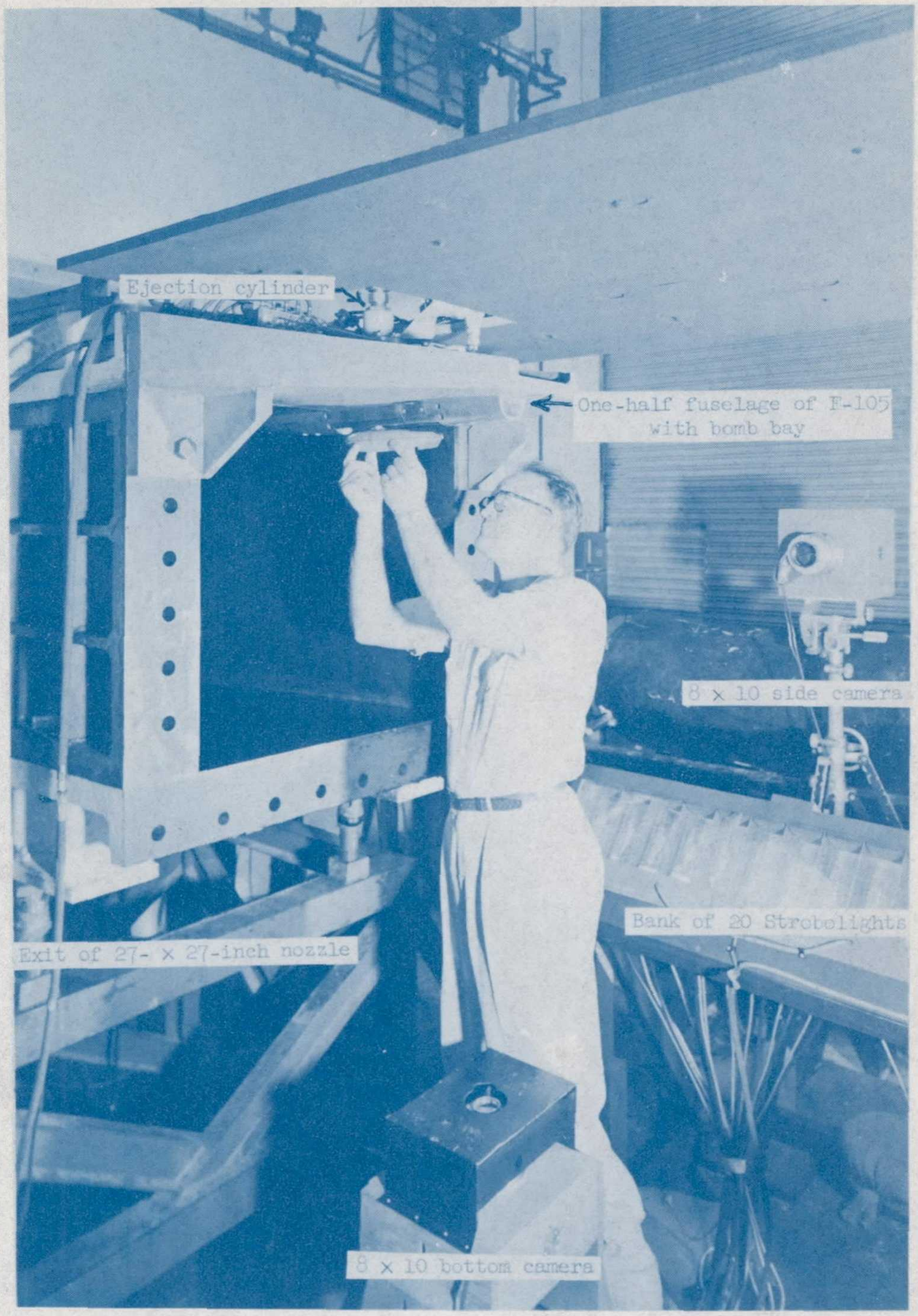
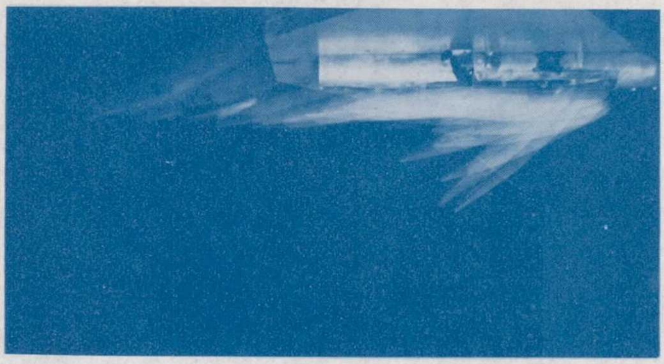
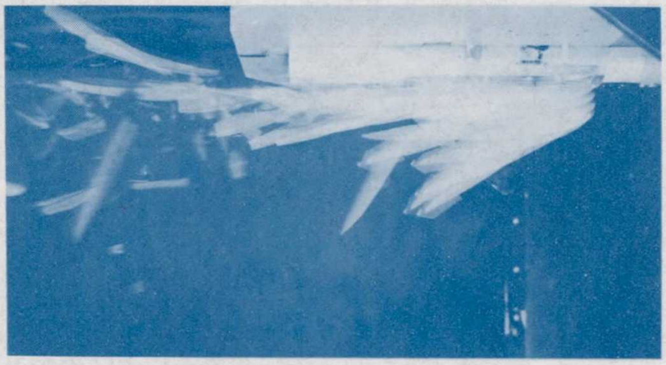


L- 86179.1

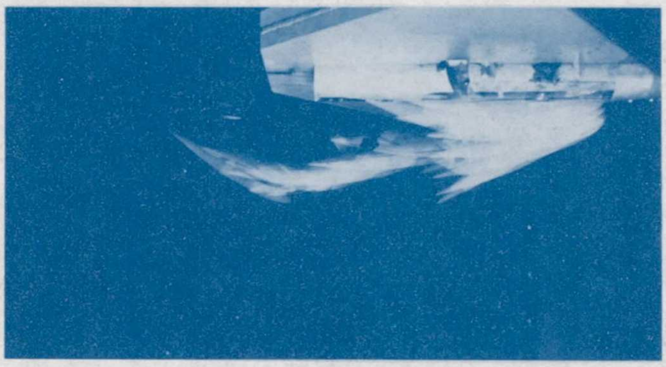
Figure 9.- Equipment setup in the preflight jet of the Langley Pilotless Aircraft Station at Wallops Island, Va.



(a) Test 1. Fins closed; h_p = 3,400 feet; $i_o = 0^{\circ}$.

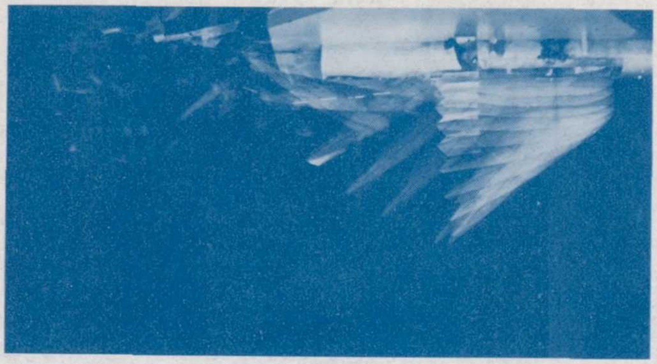


(b) Test 2. Fins closed; h_p = 3,400 feet; $i_o = 0^{\circ}$; 4° tail incidence.

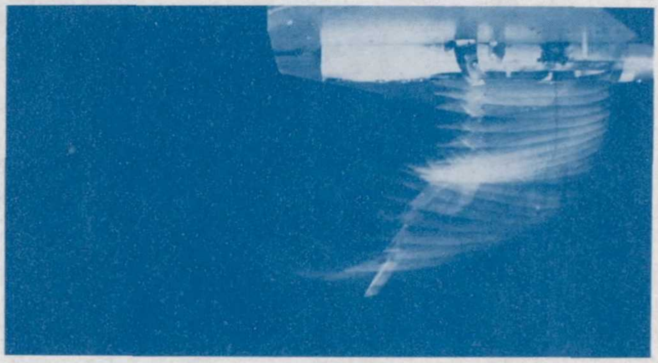


(c) Test 3. Fins open; h_p = 3,400 feet; $i_o = 0^{\circ}$. L-93533

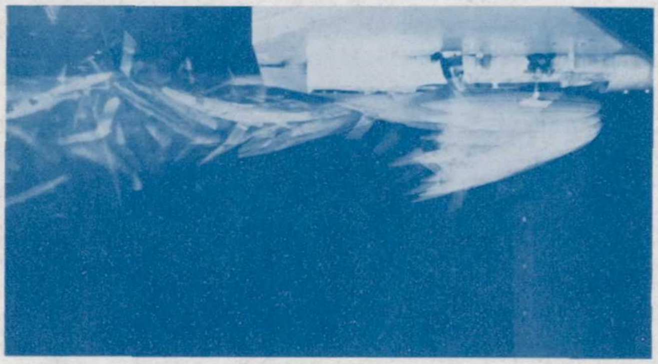
Figure 10.- Store ejections at $M_o = 1.4$. $\dot{z}_o$ = 30 feet per second.



(d) Test 4. Density check; h_p = 29,000 feet; $i_o = 0^o$.



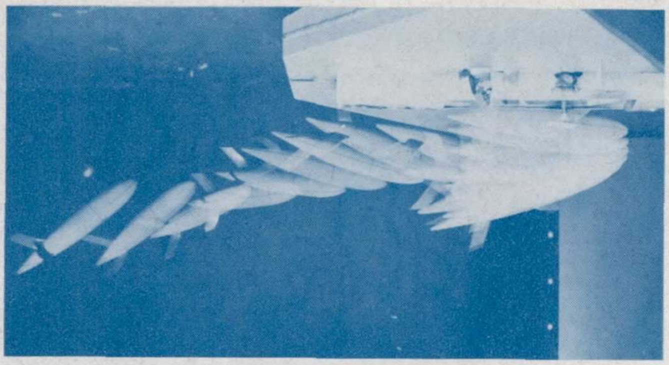
(e) Test 5. Density check; h_p = 29,000 feet; $i_o = 0^o$.



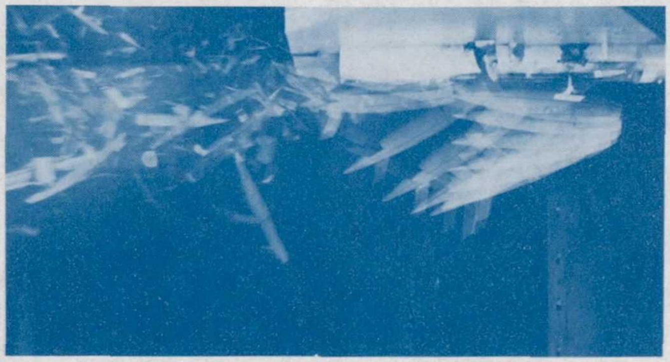
L-93534

(f) Test 6. Angle-of-incidence change; h_p = 3,400 feet; $i_o = -4^o$; fins curl.

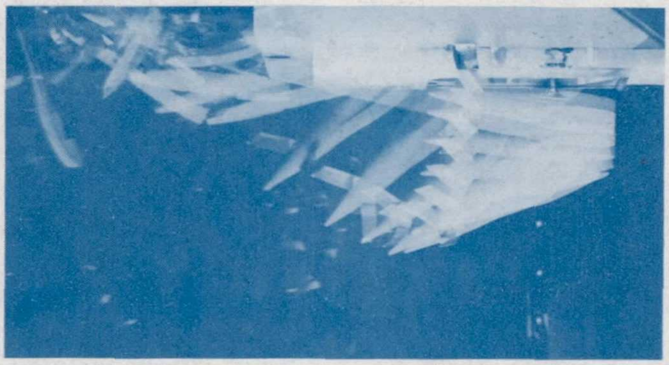
Figure 10.- Continued.



(g) Test 7. Angle-of-incidence change; h_p = 3,400 feet; $i_o = -6^\circ$; fins curl.



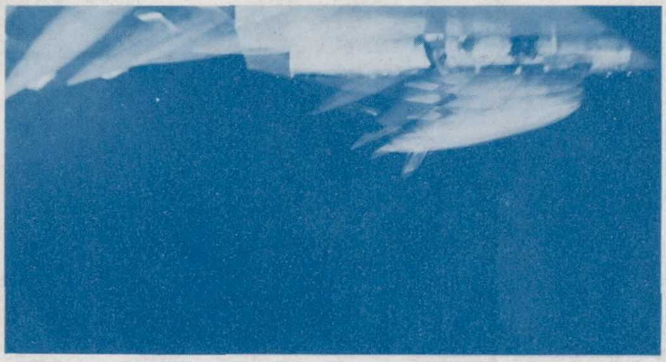
(h) Test 8. Blunt-nose modification; h_p = 3,400 feet; $i_o = -6^\circ$; fins curl.



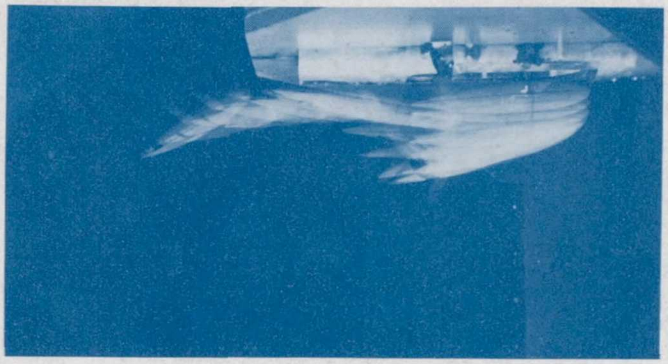
L-93535

(i) Test 9. Two-dimensional nose modification; h_p = 3,400 feet; $i_o = -4^\circ$; fins curl.

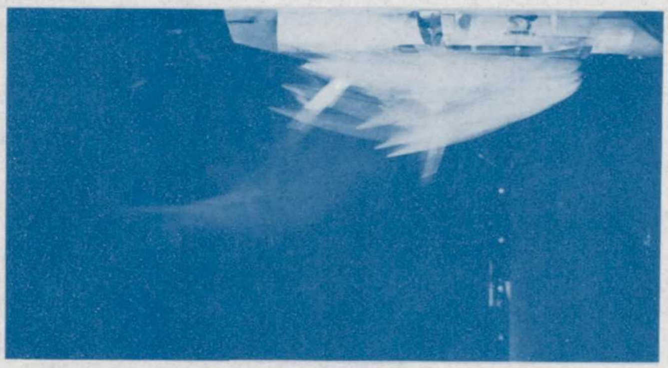
Figure 10.- Continued.



(j) Test 10. Fins rotated 180°; h_p = 3,400 feet; $i_o = 0^\circ$; fins curl.



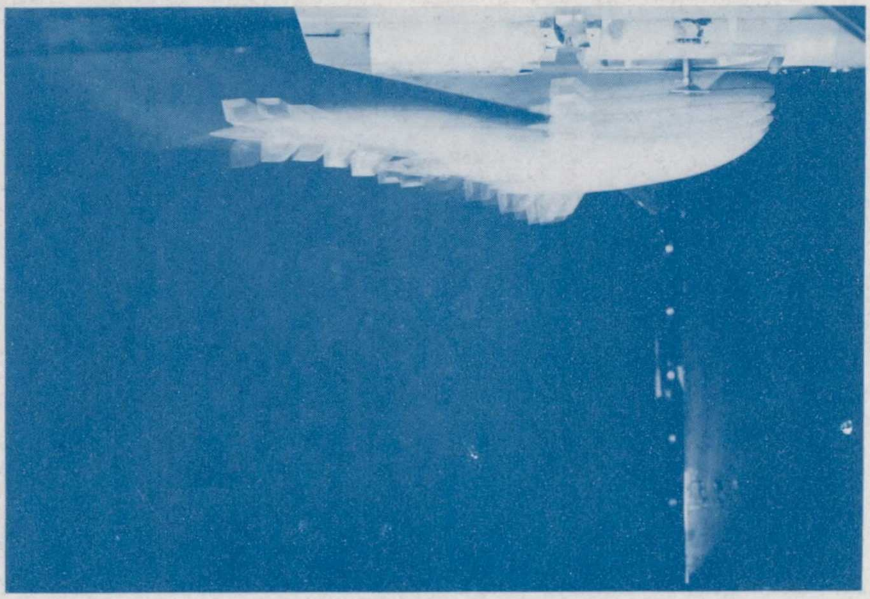
(k) Test 11. Release point extended; $z/l = 0.07$; h_p = 3,400 feet; $i_o = 0^\circ$.



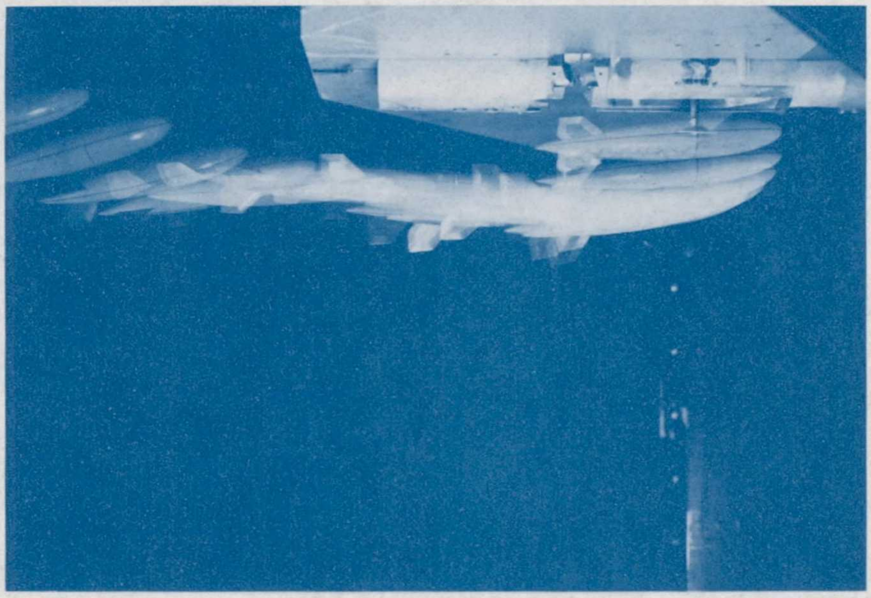
L-93536

(l) Test 12. Stiffer fins; h_p = 3,400 feet; $i_o = 0^\circ$.

Figure 10.- Continued.



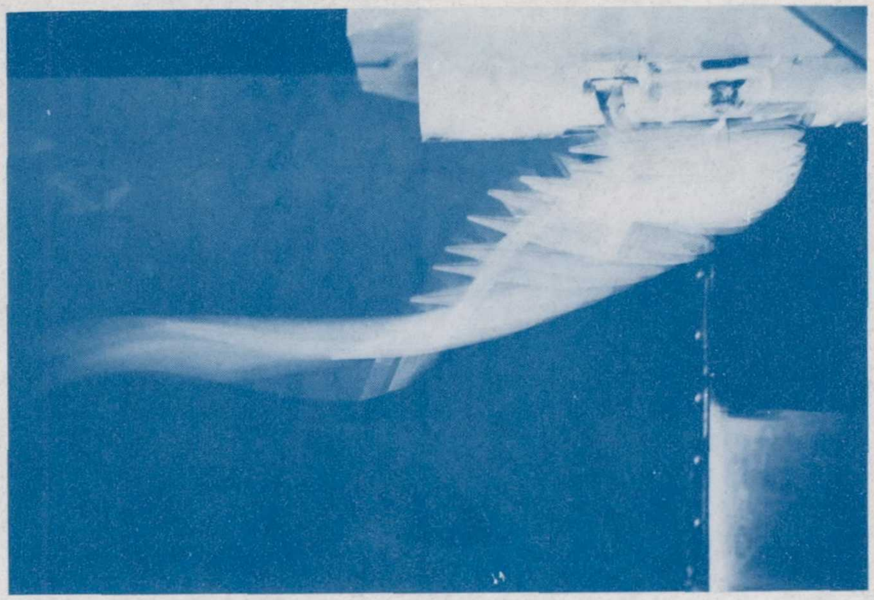
(m) Test 13. Low-aspect-ratio fins; h_p = 3,400 feet; $i_o = 0^\circ$.



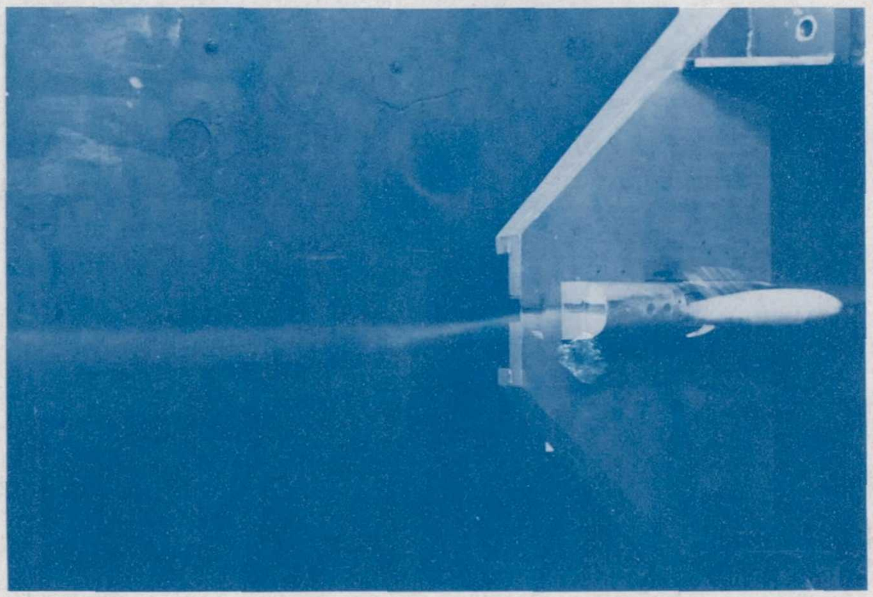
(n) Test 14. Low-aspect-ratio fins; repeatability.

L-93537

Figure 10.- Concluded.

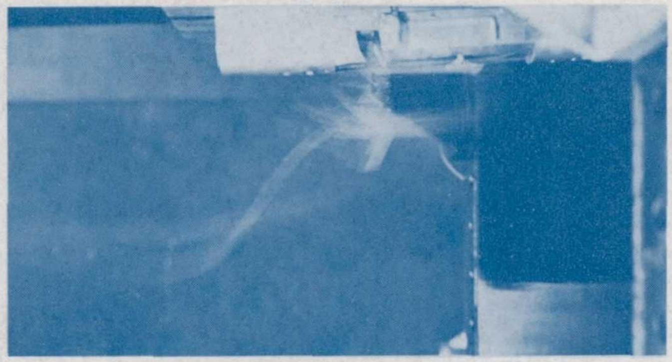


(a) Test 15. $\alpha_f = 3^\circ$; $i_o = 0^\circ$.

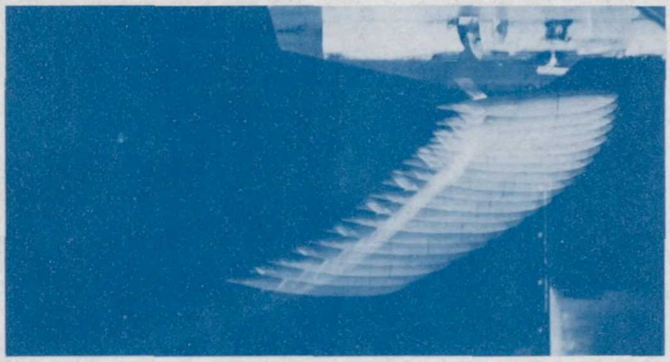


(b) Test 15. Bottom view. L-93538

Figure 11.- Store ejections at $M_o = 1.98$. $h_p = 29{,}000$ feet; $\dot{z}_o = 30$ feet per second.



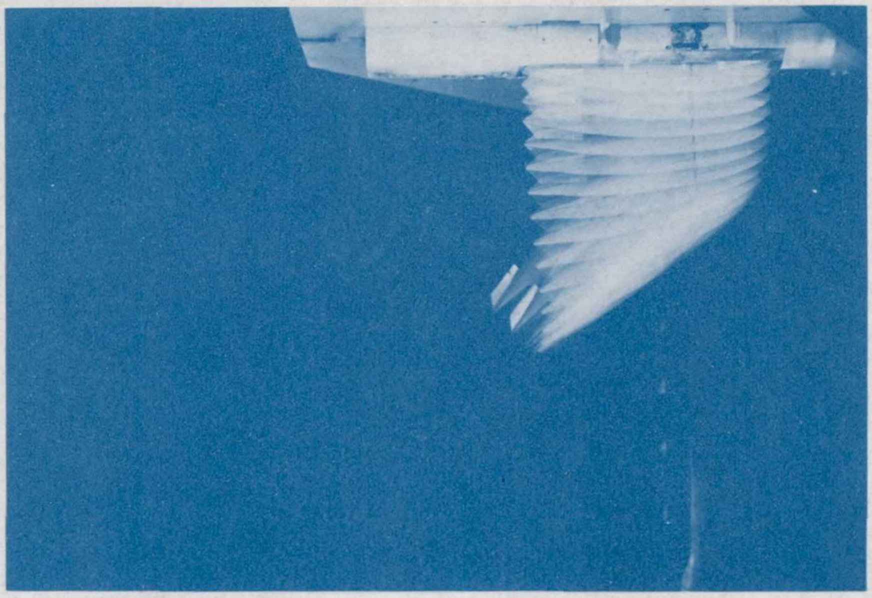
(c) Test 16. Repeatability; $\alpha_f = 3^\circ$; $i_o = 0^\circ$.



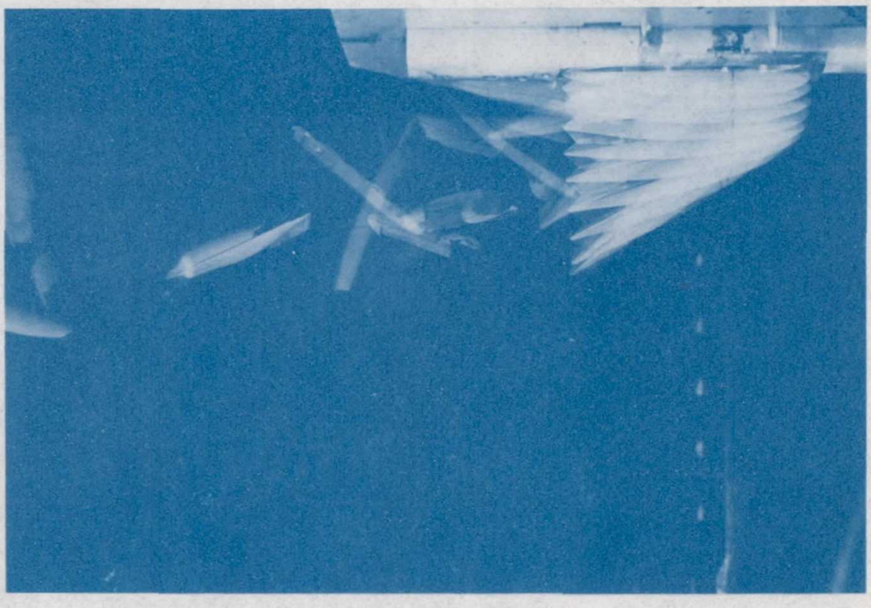
(d) Test 17. $i_o = -4^\circ$.

(e) Test 18. Fins rotated 180°; $i_o = 0^\circ$. L-93539

Figure 11.- Concluded.

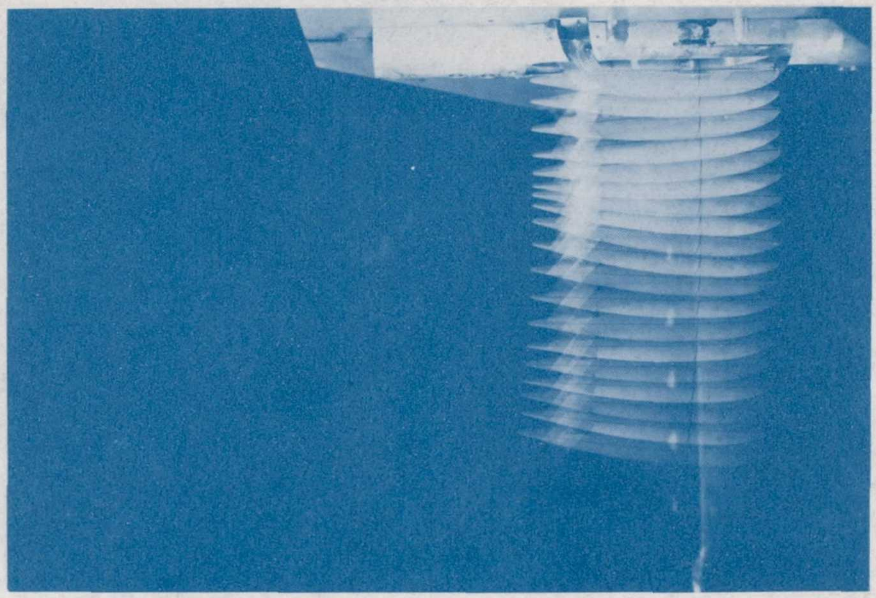


(a) Test 19. Fins closed; $\dot{z}_o$ = 30 feet per second.

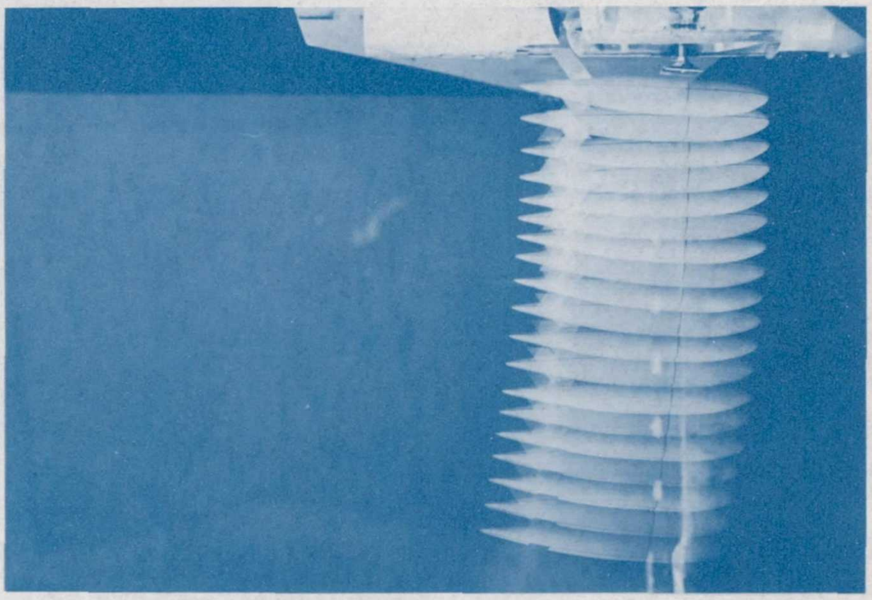


(b) Test 20. Fins closed; $\dot{z}_o$ = 20 feet per second. L-93540

Figure 12.- Store ejections at M_o = 0.80. h_p = 3,400 feet.



(c) Test 21. Fins open; $i_o = 0^\circ$.



(d) Test 22. Fins open; $i_o = -4^\circ$. L-93541

Figure 12.- Concluded.

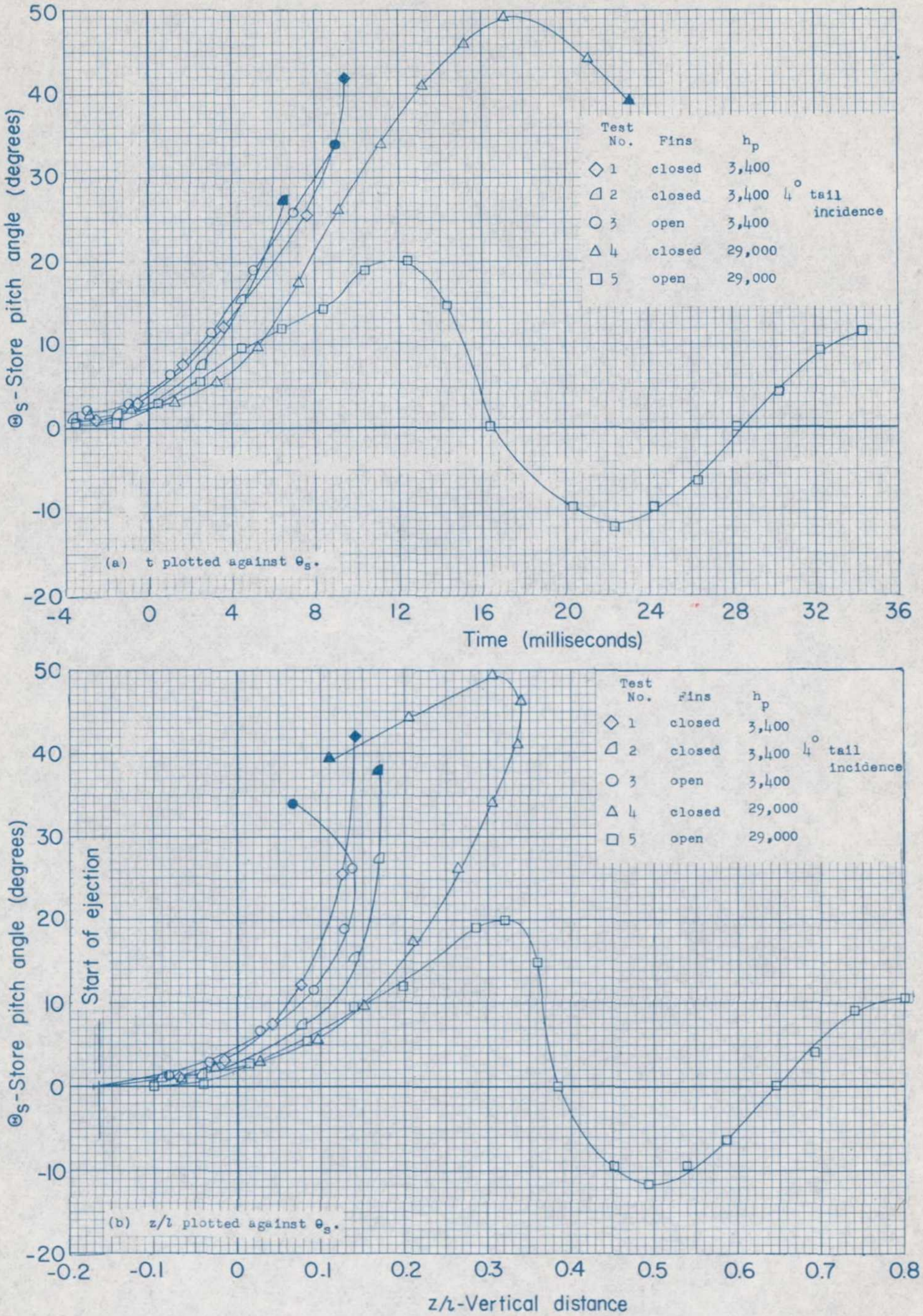


Figure 13.- Time-history and ejection plots showing the effects of fins open and closed and density changes at $M_o = 1.4$ and $i_o = 0^o$. Zero time is time of release of the store; darkened symbols indicate impact.

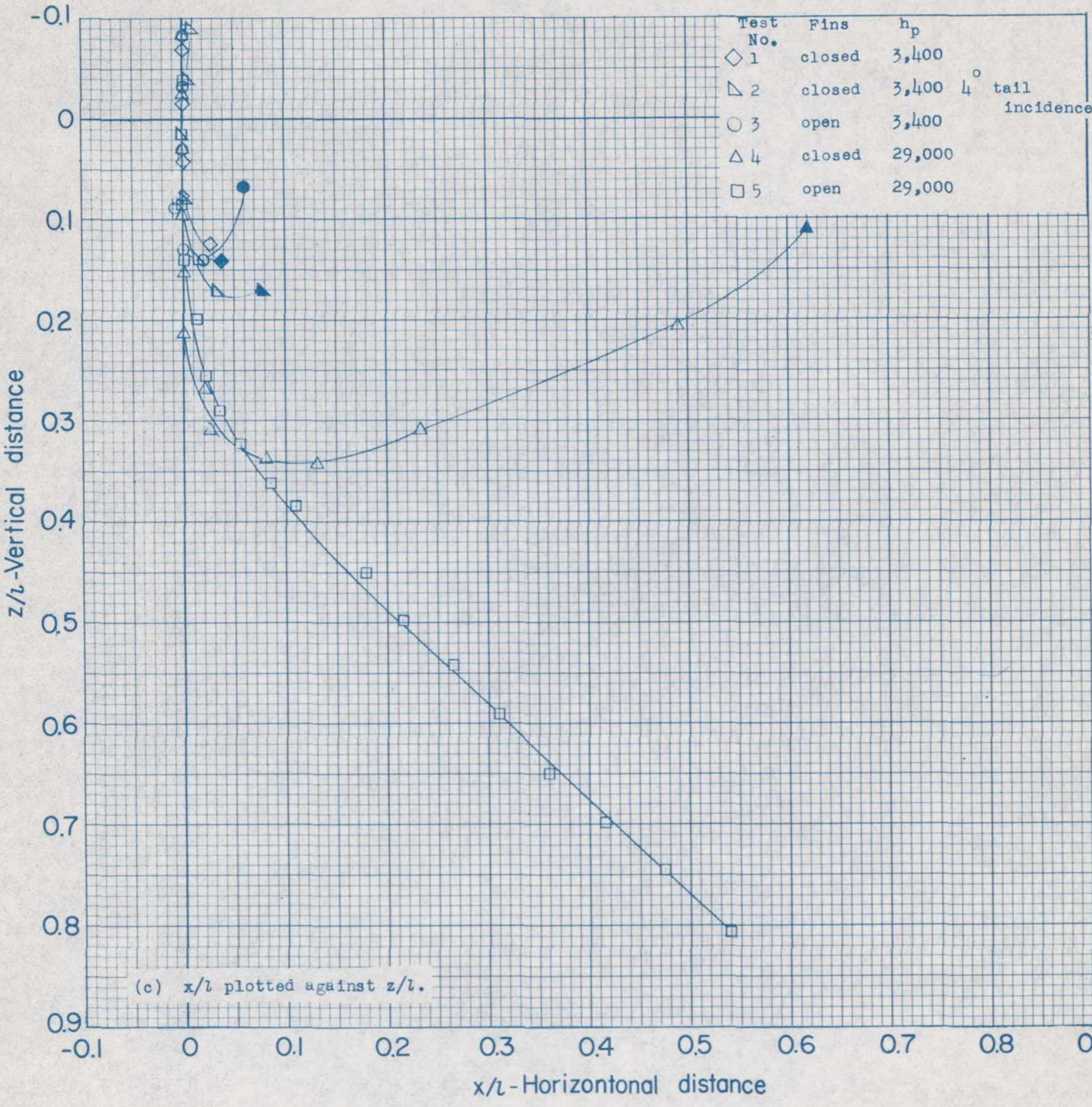


Figure 13.- Concluded.

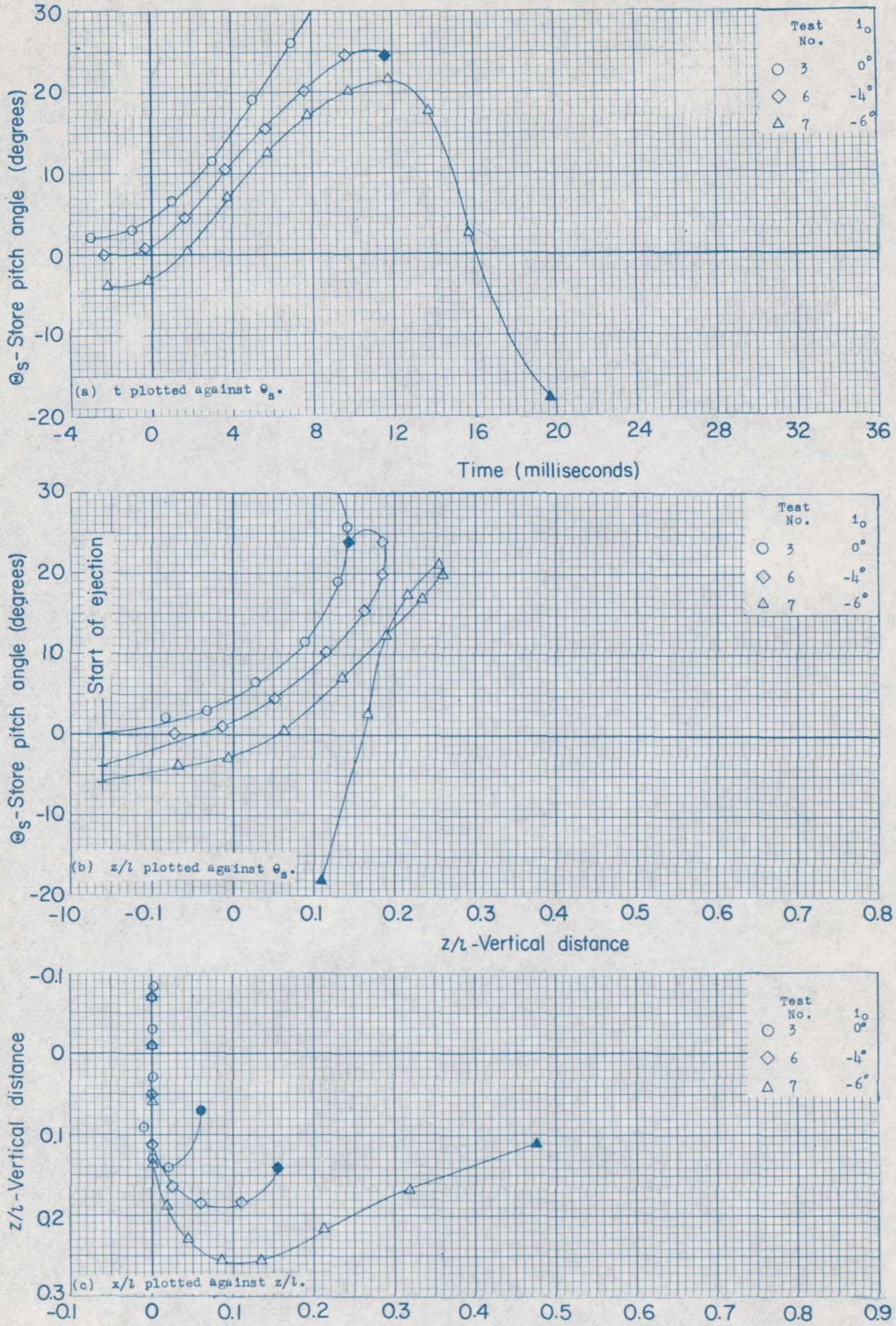
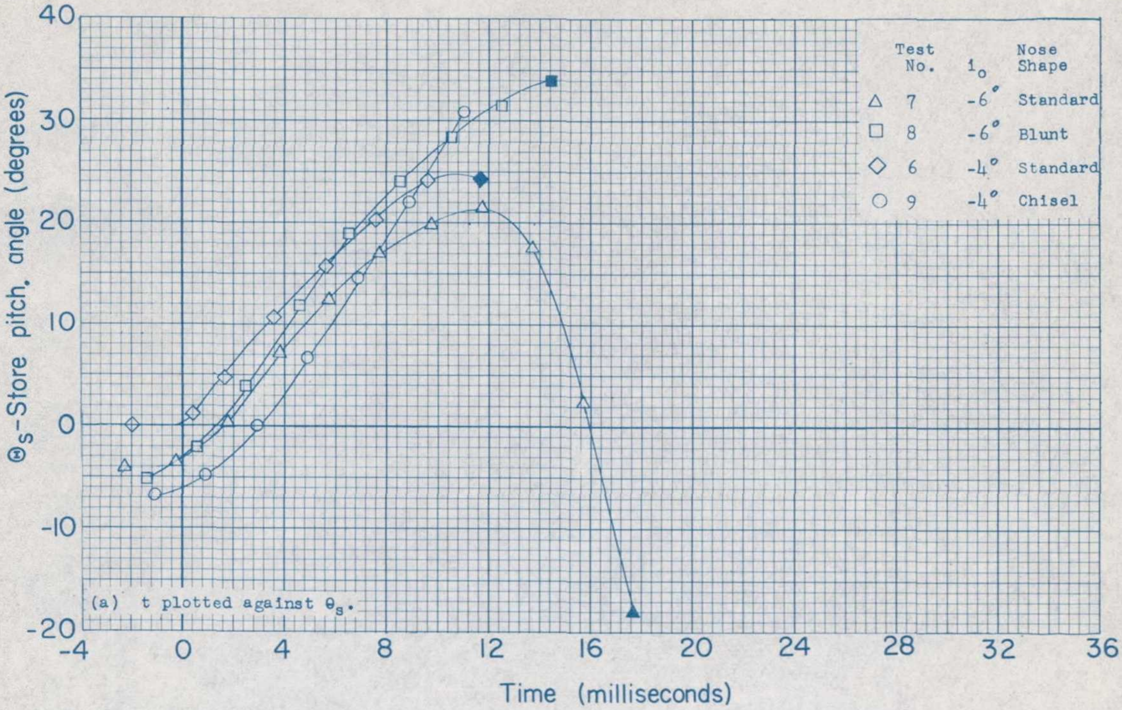


Figure 14.- Time-history and ejection plots showing the effects of angle-of-incidence change with fins open at $M_o = 1.4$. $h_p = 3,400$ feet.



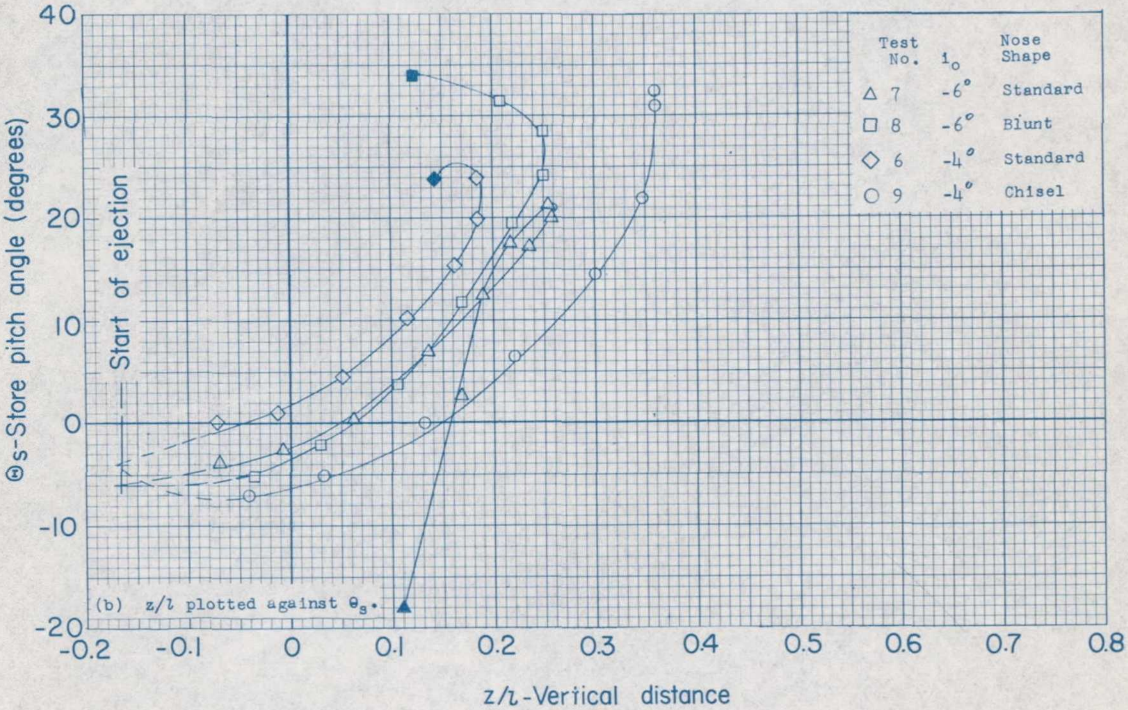


Figure 15.- Time-history and ejection plots showing the effects of nose modifications at $M_o = 1.4$. $h_p = 3,400$ feet.

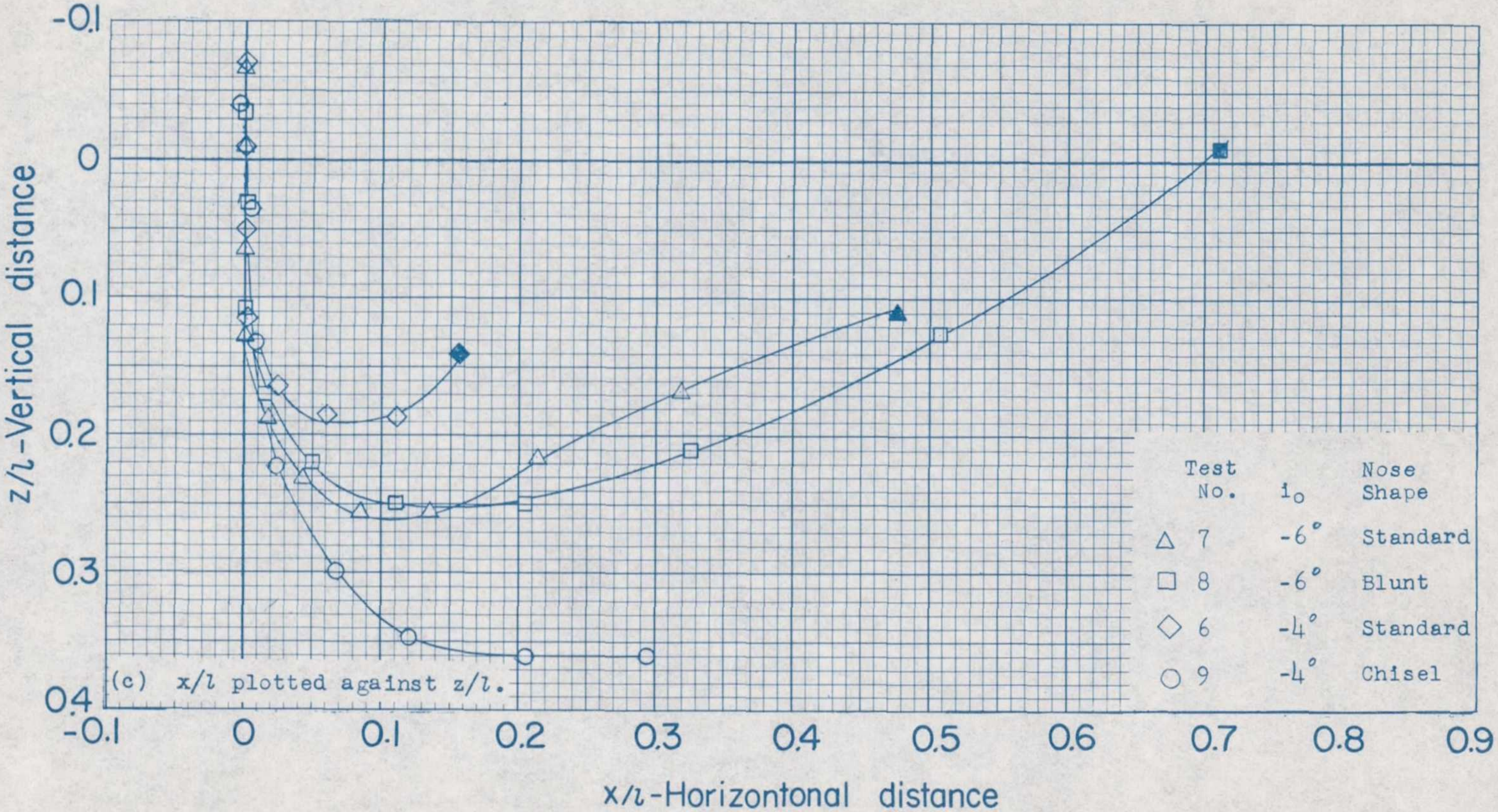


Figure 15.- Concluded.

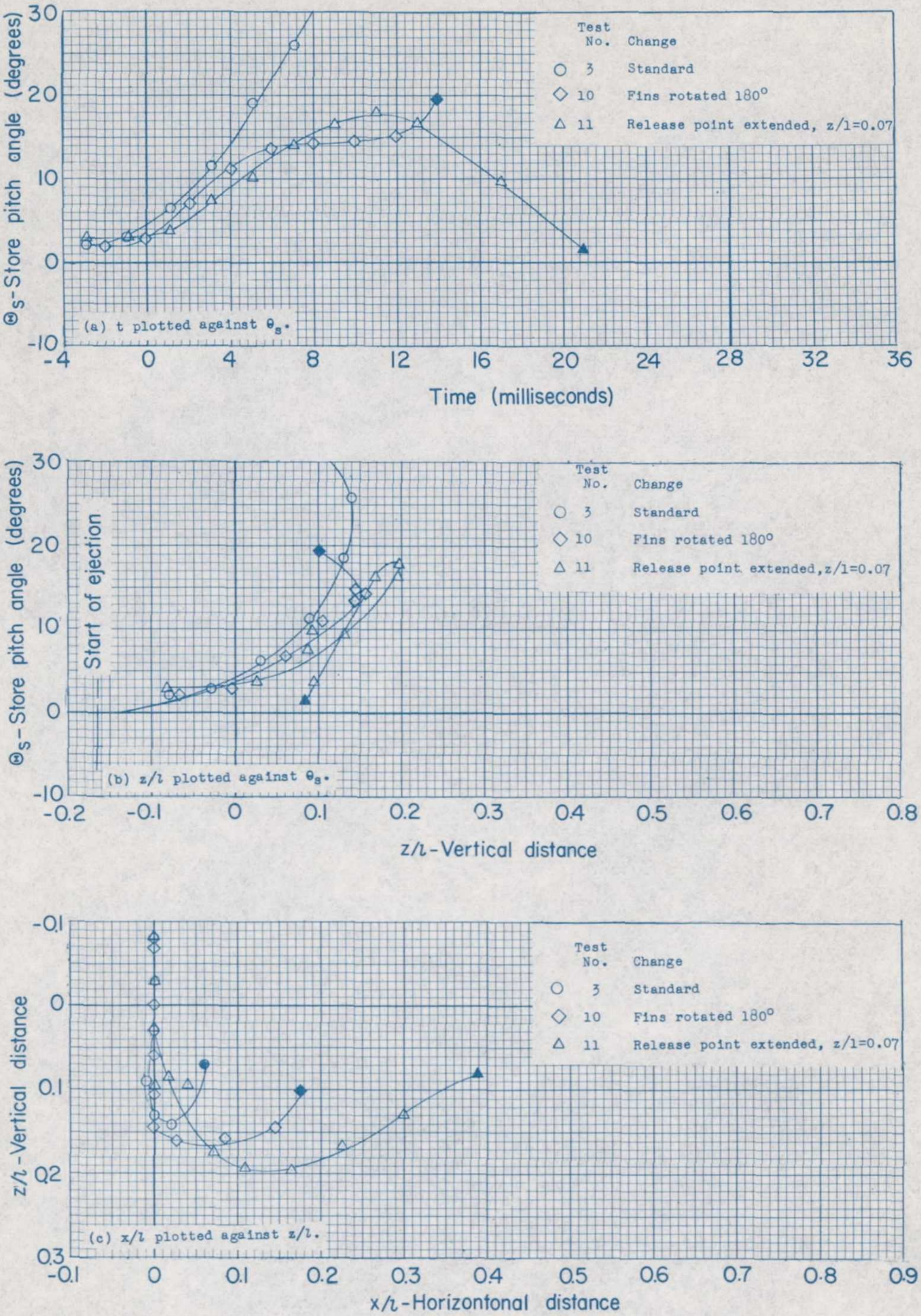


Figure 16.- Time-history and ejection plots showing the effects of changing fin position at $M_o = 1.4$. $h_p = 3,400$ feet.

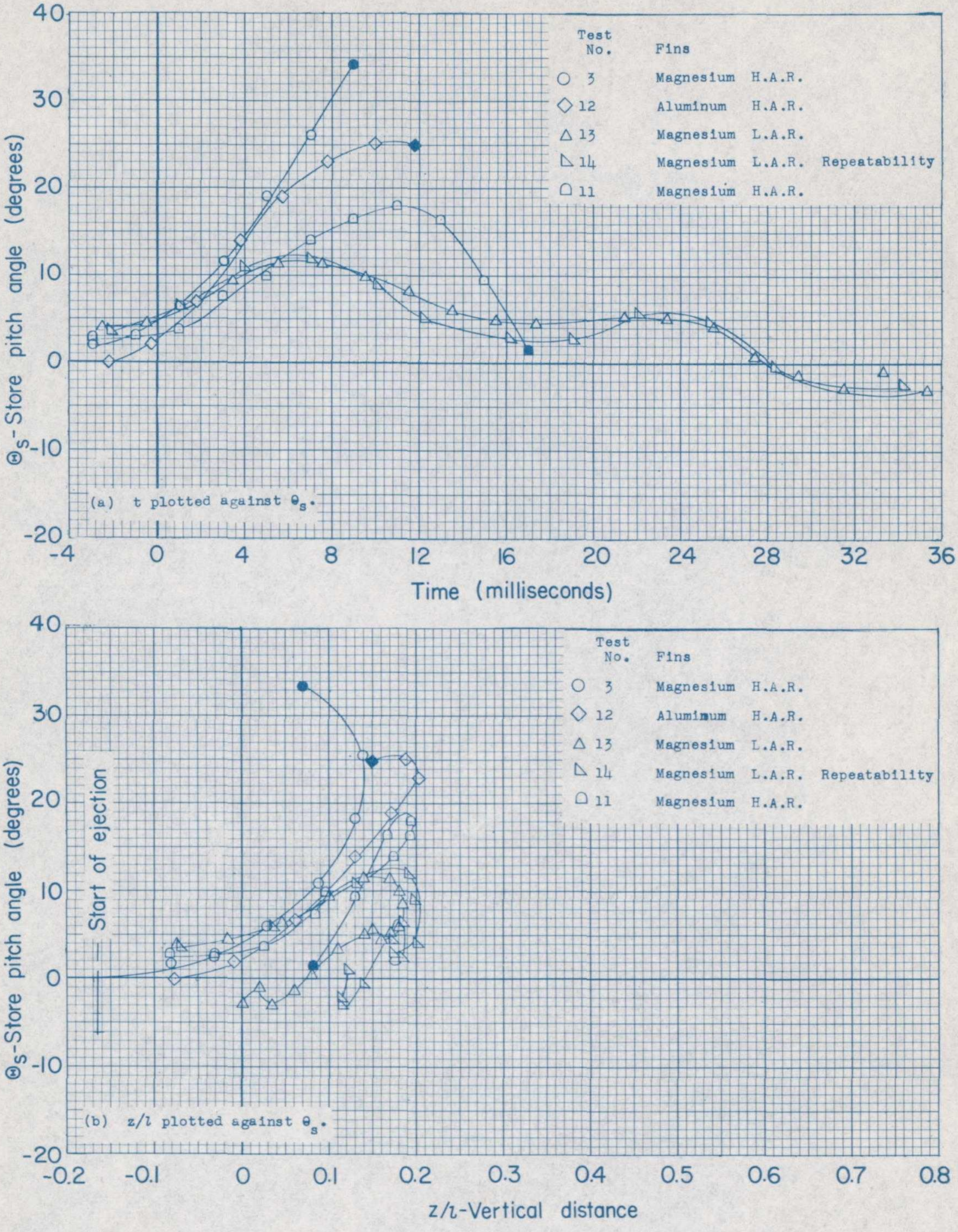


Figure 17.- Time-history and ejection plots showing the effects of fin changes at $M_o = 1.4$ and $h_p = 3,400$ feet.

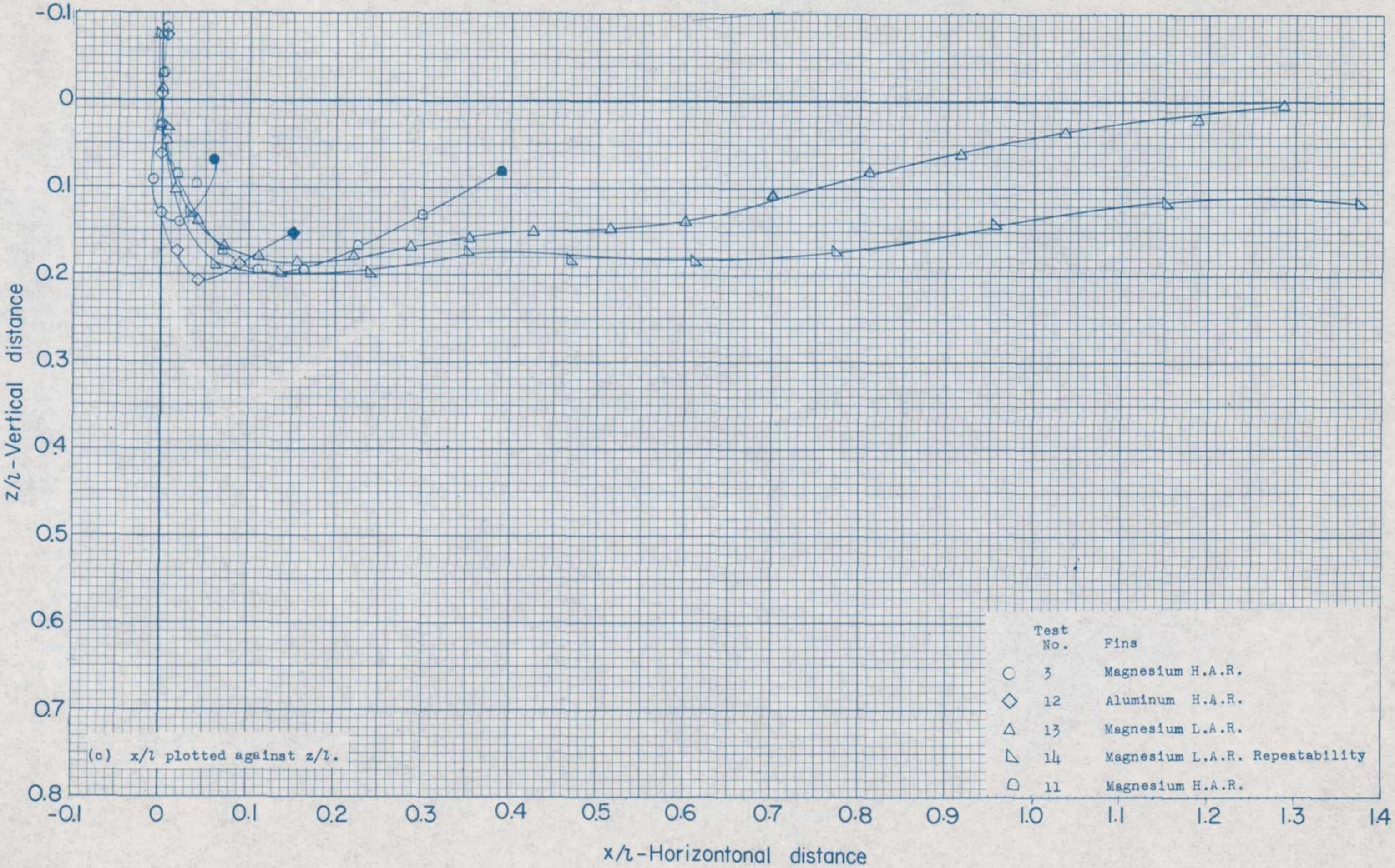


Figure 17.- Concluded.

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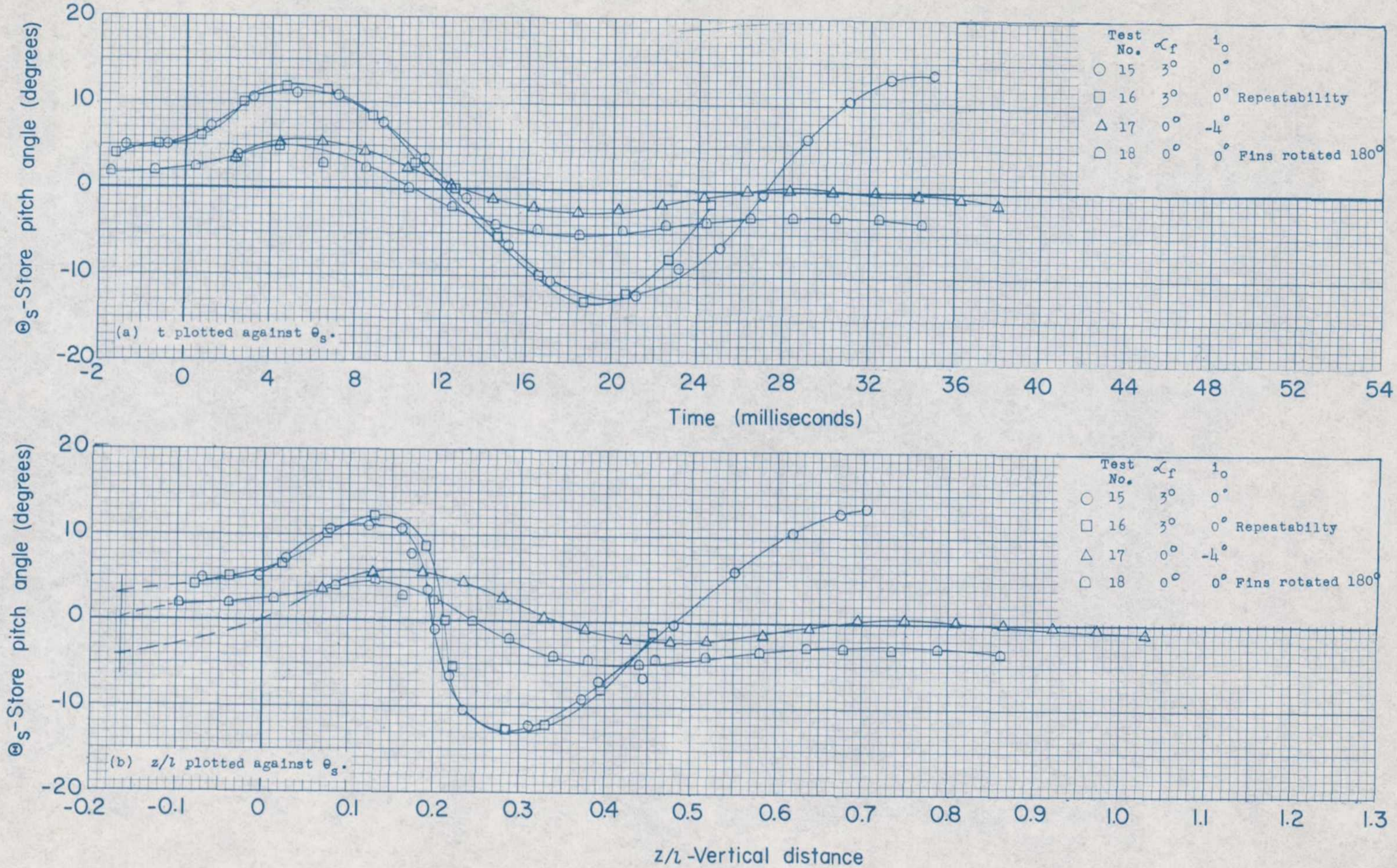

Figure 18.- Time-history and ejection plots at M_o = 1.98 and h_p = 29,000 feet.

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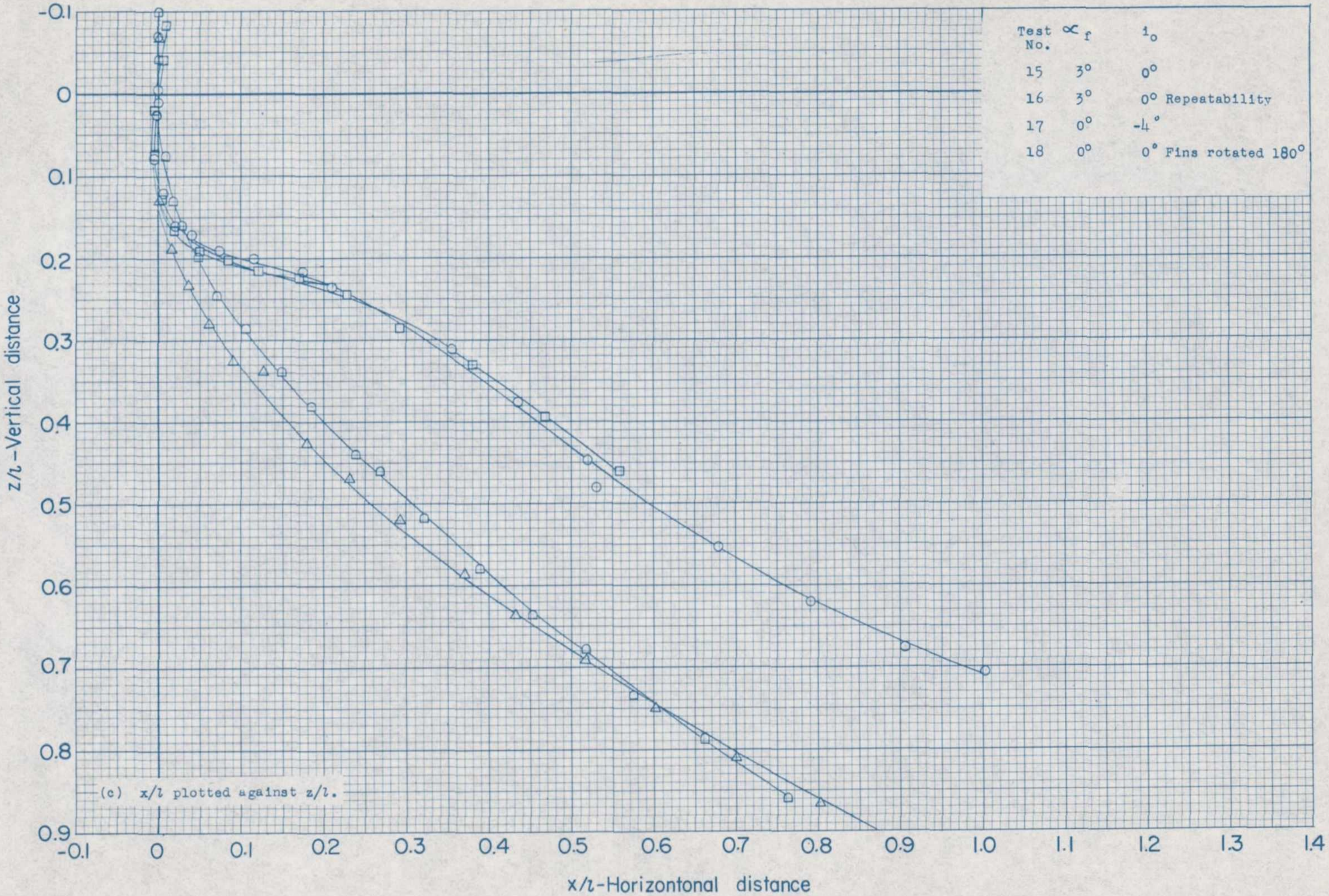

Figure 18.- Concluded.

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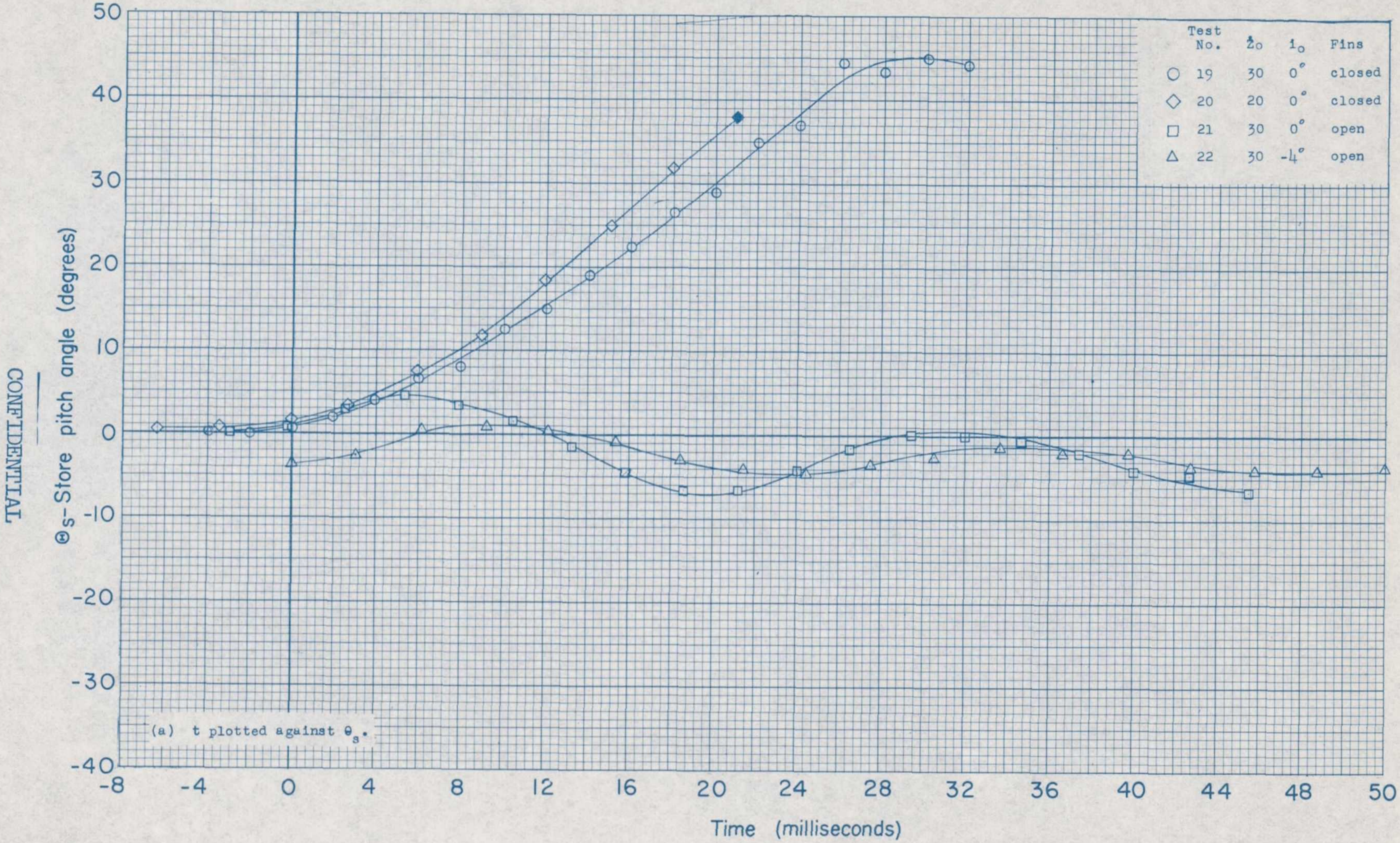

Figure 19.- Time-history and ejection plots at $M_o = 0.8$ and $h_p = 3,400$ feet.

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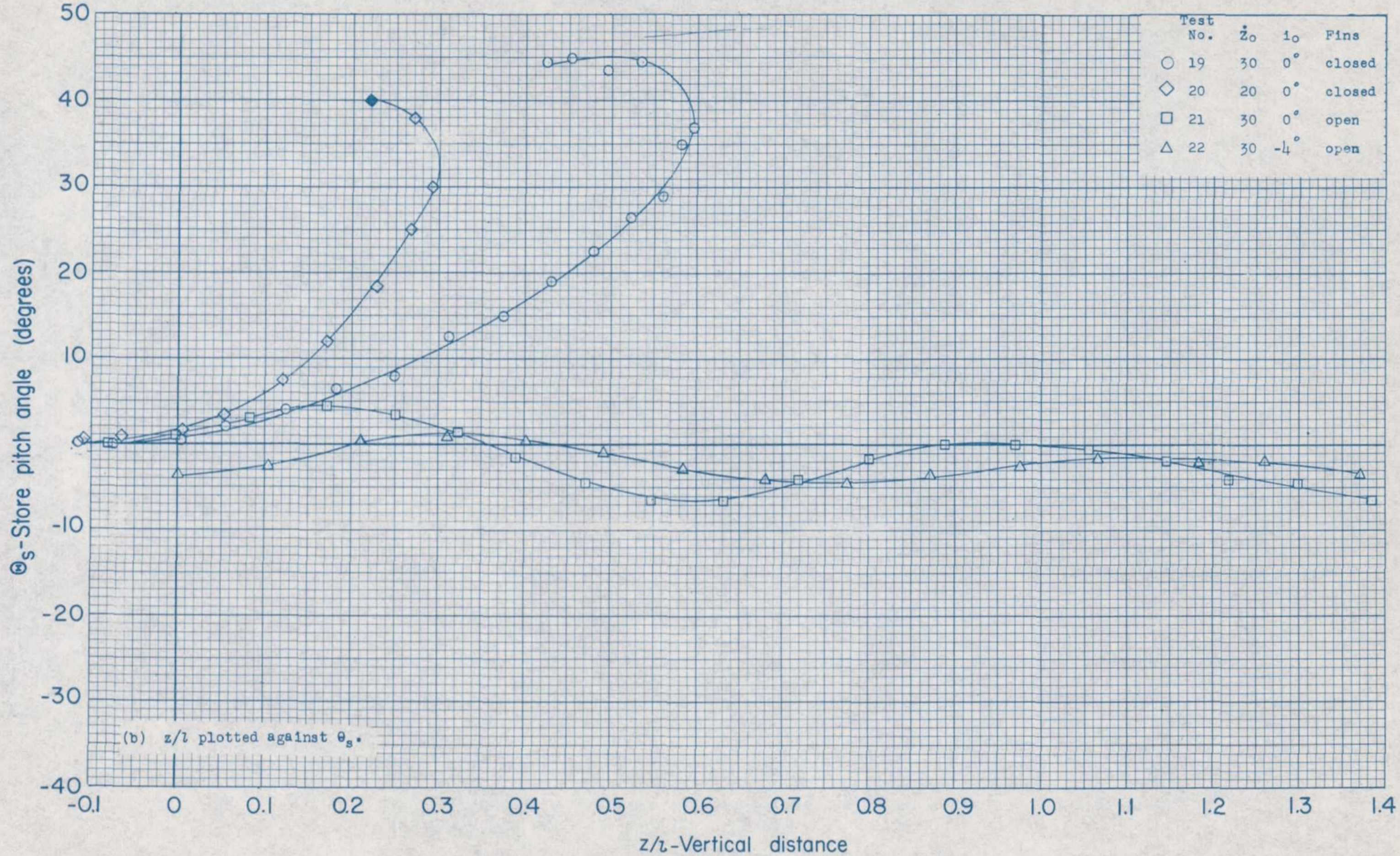

Figure 19.- Continued.

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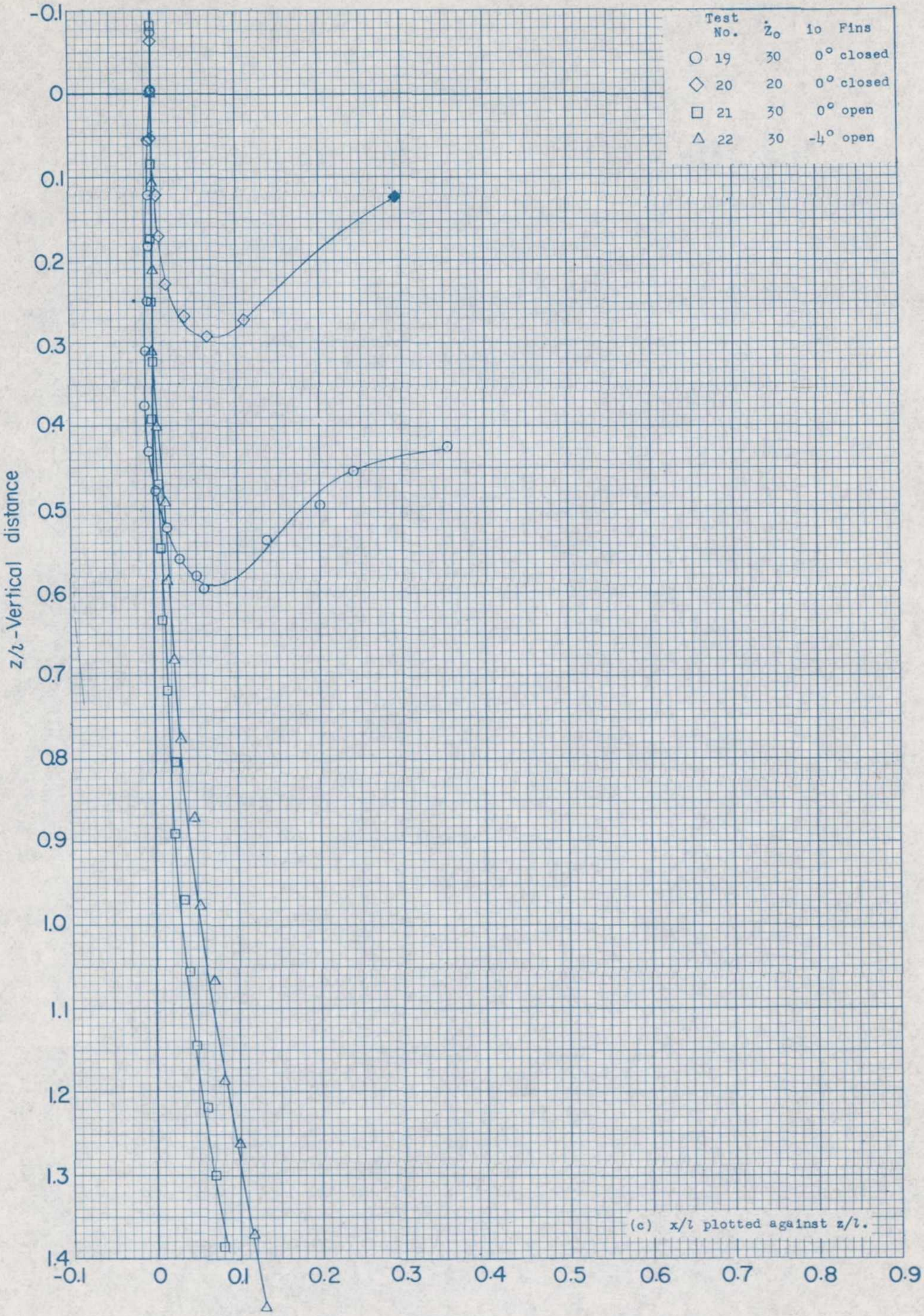
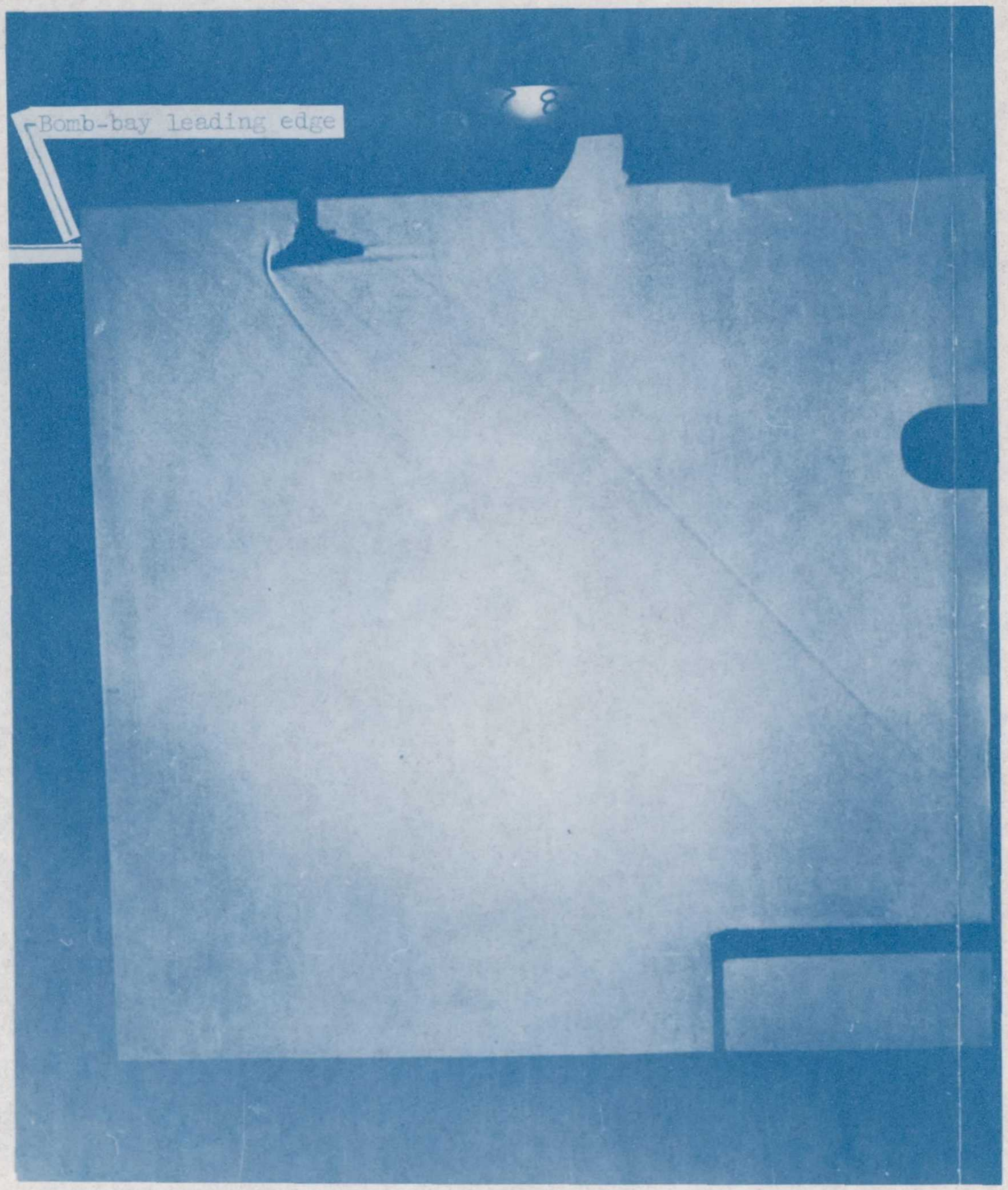


Figure 19.- Concluded.



L-93542

Figure 20.- Shadowgraph at $M_o = 1.4$ of bomb bay, ejection rod, and sway brace.

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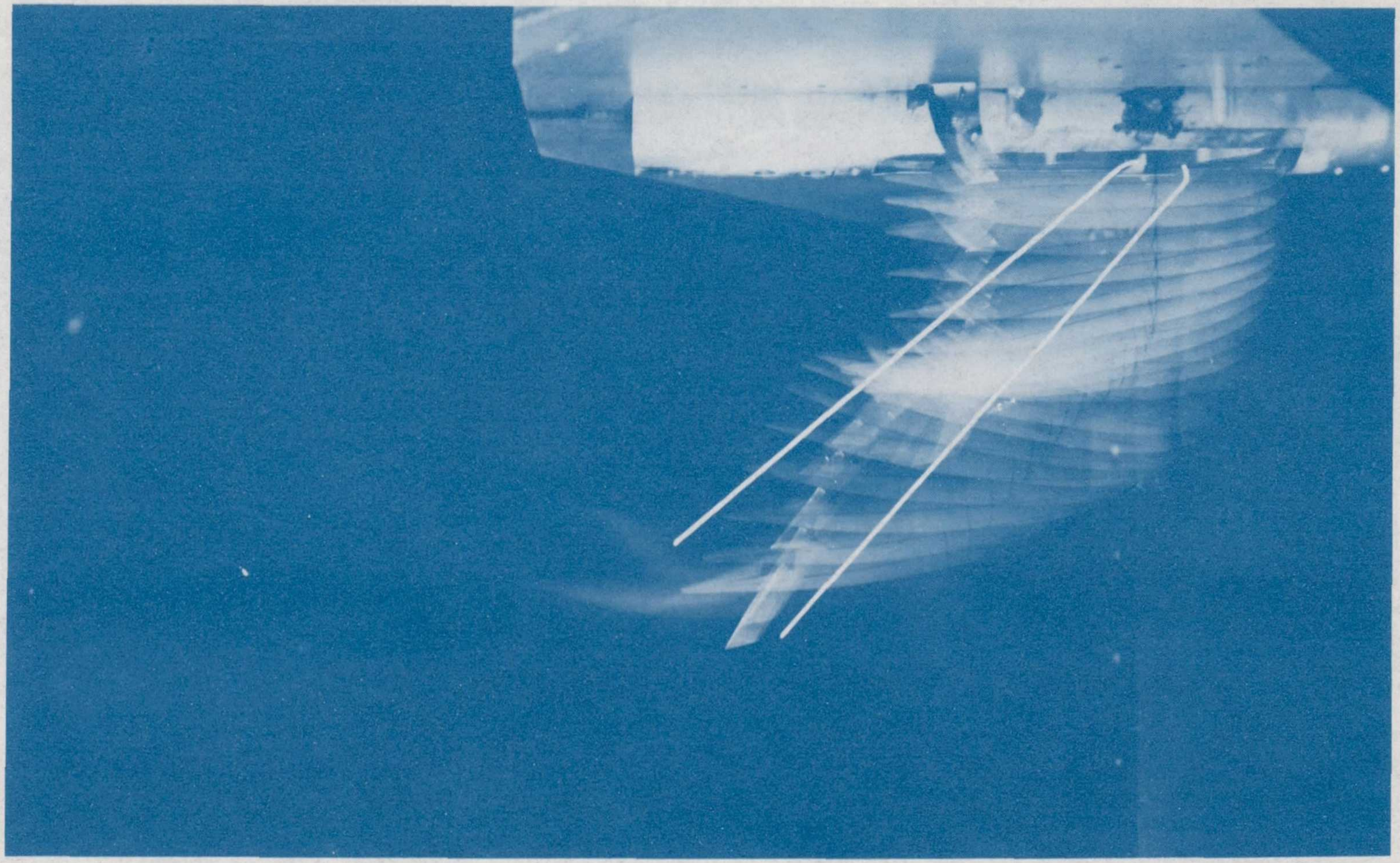

L-88705.1

Figure 21.- Sway-brace shock waves on a store ejection. Test 5.

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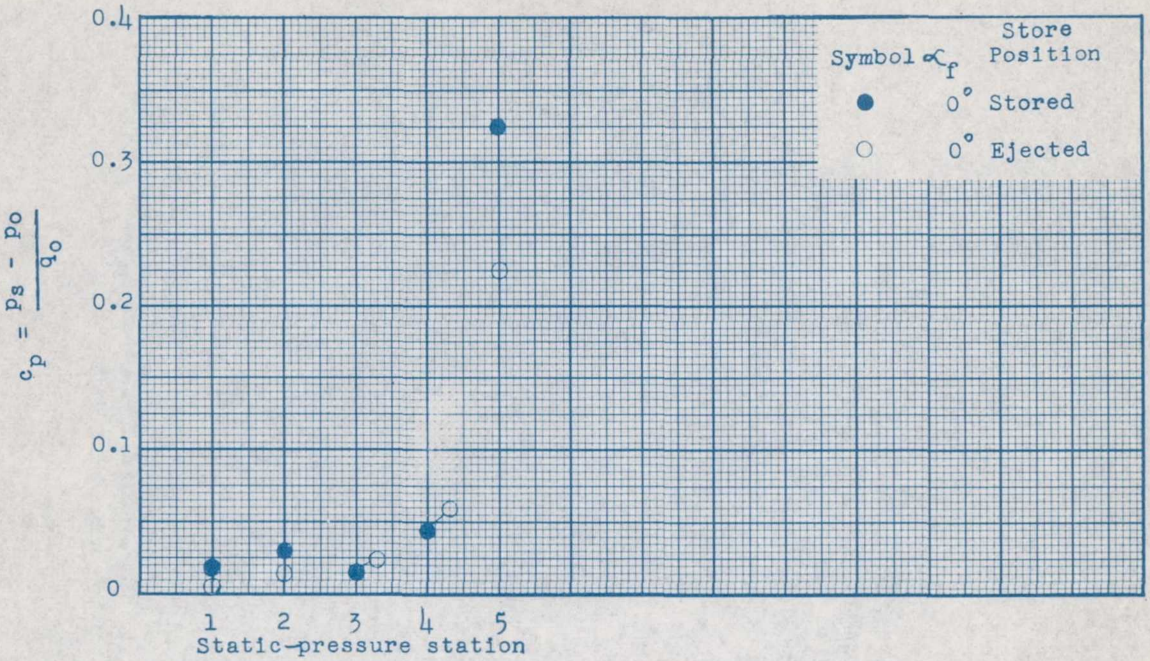
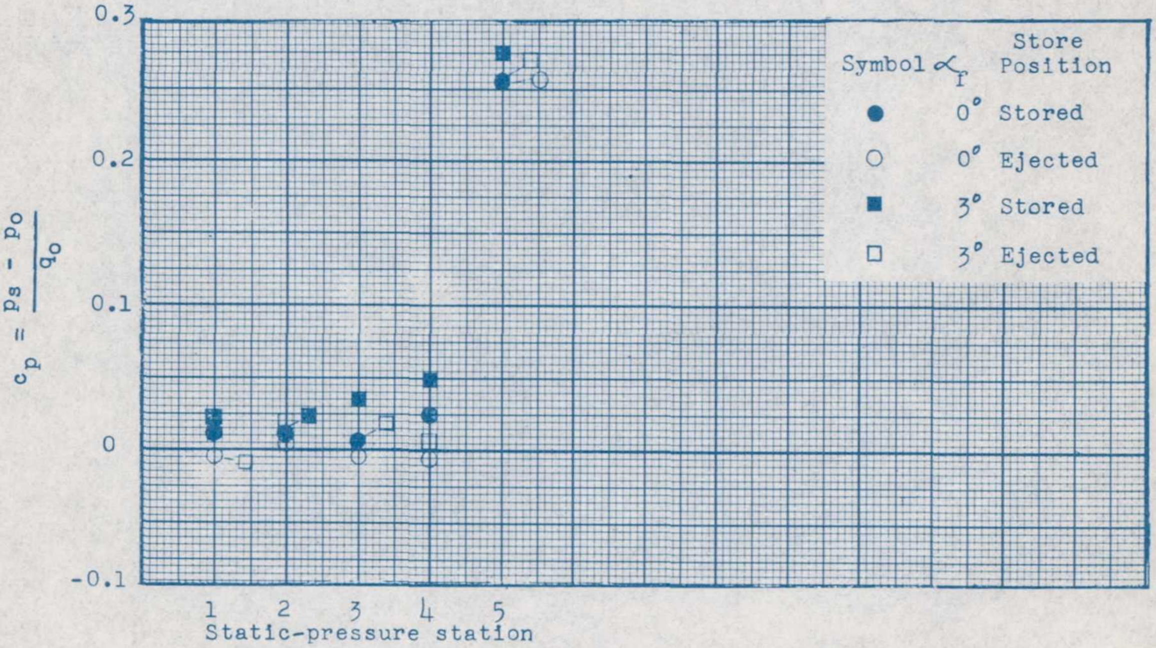


(a) $M_o = 1.40$.



(b) $M_o = 1.98$.

Figure 22.- Static-pressure coefficients in bomb bay.

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ABSTRACT

A dynamic investigation of store ejections from a simulated bomb bay of the Republic F-105 airplane has been conducted in the 27- by 27-inch preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va., at Mach numbers of 0.8, 1.4, and 1.98. A modified store with a fineness ratio of 6.00, a high aspect ratio, and swept-back fins was ejected at 20 and 30 feet per second at incidence angles of 0°, -4°, and -6°. Ejections were made of models with fins folded and with fins open. The purpose of the investigation was to determine what first-order effects were involved in making these store ejections and, in some cases, to ascertain what modifications might be made to obtain near sea-level ejections.