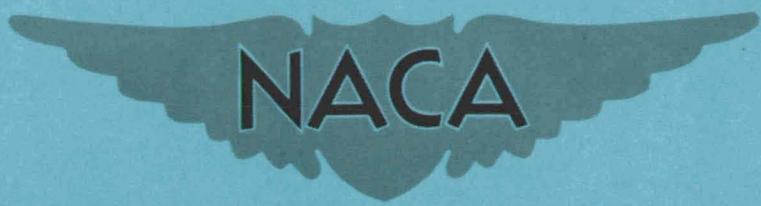


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# RESEARCH MEMORANDUM

for the

U. S. Air Force



AN INVESTIGATION OF THE RELEASE CHARACTERISTICS OF A  
1/30 DYNAMICALLY SCALED AVCO BOOSTER VEHICLE FROM  
THE SIMULATED BOMB BAY OF THE B-52 AIRPLANE

COORD. NO. AF-AM-59

By John B. Lee

Langley Aeronautical Laboratory  
Langley Field, Va.

Classified by authority of NASA  
Dated \*\* 2/8/63  
Change Notices No. 2



## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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AN INVESTIGATION OF THE RELEASE CHARACTERISTICS OF A  
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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 AVCO booster vehicle, internally carried store model from a 1/30-scale simulated bomb bay of the B-52 airplane at Mach numbers of 0.64 and 0.93. Simulated altitudes were -11,800 feet and 50,000 feet.

Successful releases were obtained at all Mach numbers and simulated altitudes of the test. Dynamic scaling was obtained by the modified light-model method and also by the heavy-model method.

## INTRODUCTION

At the request of the Wright Air Development Center, U. S. Air Force, an investigation was made to determine the release characteristics of an internally carried AVCO booster vehicle from the bomb bay of the B-52 airplane.

The primary purpose of the test program was to determine whether the AVCO booster vehicle could be free-dropped from the bomb bay of a B-52 aircraft flying at an altitude of approximately 50,000 feet at a Mach number of approximately 0.93 in a manner that would neither endanger the

carrier aircraft nor impede the function of the booster vehicle. A study of the store trajectories and oscillations that occurred near the bomb bay and after release was also made.

Dynamic scaling of the test model was obtained primarily by the light-model method and secondarily by the heavy-model method as outlined in references 1 and 2. In order to obtain proper simulation for a free release (zero ejection velocity), the modified light-model method of accelerating the airplane model away from the store (ref. 2) was used. The heavy-model method was also compared with the modified light-model method.

This investigation was made by using 1/30-scale models in the 27- by 27-inch preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va. The dynamically scaled stores simulated the full-scale configuration at an altitude of 50,000 feet for free-stream Mach numbers of 0.64 and altitudes of both -11,800 and 50,000 feet at a free-stream Mach number of 0.93 at Reynolds numbers from  $4.47 \times 10^6$  to  $6.6 \times 10^6$  per foot.

#### SYMBOLS

a	acceleration, g units
d	store diameter, in.
$h_a$	altitude simulated by airplane model due to acceleration, ft
$h_p$	simulated altitude of booster model, ft
$\theta_s$	store pitch angle in reference to the horizontal, deg
t	time, milliseconds
$\Delta t$	time interval of stroboscopic photographs
$x_s$	horizontal coordinate of store displacement, with origin at center of gravity at initial release
$z_s$	vertical coordinate of store displacement, with origin at center of gravity at initial release, in.

$z_t$  total vertical coordinate of store displacement, corrected to account for relative position with respect to accelerating air-plane model, in.  
 $W$  weight, lb  
 $I_y$  store inertia in pitch plane, lb-in.<sup>2</sup>  
 $L$  characteristic length, in.  
 $M_0$  free-stream Mach number  
 $p$  static pressure, lb/sq ft  
 $q$  dynamic pressure, lb/sq ft  
 $T_s$  tunnel static temperature, °R  
 $\alpha_w$  wing angle of attack, deg

## Subscripts:

$M$  model  
 $P$  prototype

## MODELS AND APPARATUS

## Store

A 1/30-scale model of the AVCO booster vehicle is shown in figure 1. The four-fin configuration had a roll tab on each fin. The model was smooth as shown in figure 2, whereas the full-scale store has several ribs 1 inch high along its surface (ref. 1). The first rib was located immediately behind the nose on the flat surface of the model. A 1/32-inch wire ring encircled the model at this point (station 0.840 in. model scale) for one test. In order to obtain a dynamically scaled model of the store ( $W_P = 5,590$  lb and  $I_{y_P} = 23,900,000$  lb-in.<sup>2</sup>), the model nose, tail plug, and case were made of steel for the light-model method (ref. 1). For the heavy-model method, the model nose and tail plug were made of tungsten and the case, of aluminum.

## B-52 Airplane Model

A sketch of the 1/30-scale B-52 airplane model is shown in figure 3. The wing for the test model was an NACA 65A018, 35° sweptback wing. End plates were placed 12 inches from the fuselage center line. The airplane model was attached to a single strut (fig. 4) which was free to move only in the vertical direction between rollers in the beam support.

An acceleration of 12g could be obtained from lift on the wings of the airplane model with the wings at an angle of attack of 12°. A hydraulic cylinder was attached to the end of the fuselage strut to increase the airplane model acceleration to 29g (which was the proper amount for dynamic similarity).

The nose of the fuselage was placed approximately 1/2 inch downstream from the nozzle exit.

## Photography

High-speed photographs were made by continuously illuminating the model by a series of flash bulbs that were electronically timed to overlap, and exposing the film through narrow radial slits in a rotating disk placed in front of a camera. Exposures were made at 4- and 8-millisecond intervals on a single 8- by 10-inch piece of film. The test setup is shown in figure 4.

## TESTS

### Dynamic Similarity

Two basic methods of obtaining dynamic similarity were employed in the present tests - light-model and heavy-model methods (ref. 2). Both methods require that the nondimensional radii of gyration, Mach number, air properties, air temperature of model and prototype be equal and that model and prototype be geometrically similar.

Light-model method.- In the light-model method the model weight and moment of inertia are defined by

$$W_M = \left( \frac{L_M}{L_P} \right)^3 \frac{P_M}{P_P} W_P$$



and

$$I_{y,M} = \left( \frac{L_M}{L_P} \right)^5 \frac{P_M}{P_P} I_{y,P}$$

With this method of scaling, the time to travel a distance of one characteristic length in the streamwise or x-direction, and the period and time to damp the short-period longitudinal oscillation are proportional to the characteristic length. The aerodynamically produced accelerations are inversely proportional to the characteristic length. Inasmuch as the gravity-induced acceleration cannot respond to scale changes in a manner similar to the aerodynamically induced accelerations, the vertical acceleration, velocities, and displacements are deficient. One way of circumventing this deficiency is to accelerate the parent model vertically at

a rate equal to  $\left( \frac{L_P}{L_M} - 1 \right) g$ , at the instant of store release. The trajec-

tory of the model with respect to the parent model then duplicates that of the prototype. This method (called modified-light-model method) was employed in most of the present tests. It should be noted that the modified-light-model method gives essentially an exact simulation of the prototype motion except for the component of the angle of attack produced by the vertical velocity of the airplane fuselage. For a maximum velocity of 27 feet per second obtained in this investigation the maximum angle is only approximately  $1.5^\circ$ .

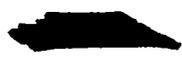
Heavy-model method.- In the heavy-model method the model weight and moment of inertia are given by

$$W_M = \left( \frac{L_M}{L_P} \right)^2 \frac{P_M}{P_P} W_P$$

and

$$I_{y,M} = \left( \frac{L_M}{L_P} \right)^4 \frac{P_M}{P_P} I_{y,P}$$

In this method, the aerodynamically produced accelerations are independent of the scale and the length in the x-direction. The period and velocity change are proportional to the square root of the characteristic length  $L$ . The time to damp to  $1/2$  amplitude is independent of model size. The number of cycles required to damp to  $1/2$  amplitude is inversely proportional to the square root of  $L$ , and the model will therefore be underdamped when compared to the full-scale booster.



Detailed methods of scaling are given in reference 2. Only expressions for model weight and inertia have been given herein; the relation between model and prototype motion has been stated without proof.

The maximum altitude simulated with a heavy model constructed from practical materials was -11,800 feet (ref. 2).

### Test Methods

The store was held inside the bomb bay until the tunnel exit static pressure was adjusted to ambient static pressure. The airplane model strut was unlocked and allowed to accelerate upwards. At the instant of release of the airplane model, a break link on top of the store (fig. 2) was broken and the store allowed to fall free. The release of the airplane model was synchronized with the flash bulbs and camera shutter and a stroboscopic photograph was obtained of the drop.

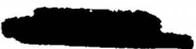
A relatively constant acceleration could be obtained from lift on the wings alone (fig. 5). With the use of the piston the desired initial acceleration of 29g was obtained. However, after approximately 16 milliseconds the acceleration decreased, reaching 0 at approximately 50 milliseconds. The test results are therefore conservative in that the bomber was closer to the store than would be expected for full scale during the period after 16 milliseconds (model scale time).

### RESULTS AND DISCUSSION

Table I lists the pertinent information of each test. The model weights and inertias are scaled for a simulated altitude of 50,000 feet. The initial acceleration of the airplane model and the corresponding altitude for the airplane model acceleration are listed. Presented in figure 6 are the stroboscopic photographs of the store drops from which the test data were obtained.

Presented in figure 7 is a set of time-history plots of the store oscillations  $\theta_s$  and store displacements  $x_s/d$  and  $z_s/d$ . The flagged symbols indicate the total corrected trajectory (that is,  $z_t/d$ ) of store displacement relative to the airplane model for the cases where the airplane model was accelerated. Zero time was taken to correspond with the first photograph that showed the store emerging from the bomb bay and consequently is not necessarily the same for different tests.

The store trajectories are plotted in figure 8. The zero point for the store trajectory was the center of gravity point of the store at release, which was inside the bomb bay. The shaded symbols indicate the



approximate position of the store inside the bomb bay as obtained from the displacement of the airplane fuselage. Store pitch oscillations and trajectories are repeated in figure 9 for comparison with other test conditions.

The stroboscopic photographs of the tests (fig. 6) show that satisfactory releases were obtained in all cases from simulated altitudes below sea level, -11,800 feet, to high altitudes of 50,000 feet at  $M_0 = 0.93$ . Maximum pitch amplitudes of  $13^\circ$  and  $-10^\circ$  were reached at  $M_0 = 0.93$  and a simulated altitude of 50,000 feet (fig. 9(a)). The store pitch oscillations repeat within  $5^\circ$  and the total store trajectory appears identical for a drop of over four store diameters. Changing the wing angle of attack to  $6^\circ$  (fig. 9(b)) showed no significant change in the store release characteristics.

A ring on the nose of the store (fig. 9(c)) appeared to cause a shift in the store pitch-time curve of approximately 14 milliseconds, but the maximum pitch amplitudes were the same.

A decrease in Mach number (fig. 9(d)) caused a large increase in the pitching period with little or no change in maximum pitch amplitudes.

Maximum pitch amplitudes of  $13.5^\circ$  and  $-8.5^\circ$  were reached with the heavy model method (fig 7(f)) at a simulated altitude of -11,800 feet.

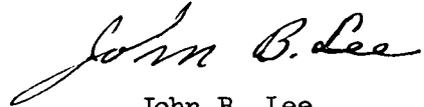
Little or no change was noted in the store trajectory for all the cases tested for the first four store diameters (fig. 9).

#### CONCLUDING REMARKS

An experimental investigation was 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 AVCO booster vehicle from a 1/30-scale simulated bomb bay of the B-52 airplane at free-stream Mach numbers of 0.64 and 0.93. As a result of this investigation it is concluded that the AVCO booster

vehicle may be successfully released from the bomb bay of the B-52 at the altitudes and Mach numbers simulated in the tests.

Langley Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va., September 5, 1956.



John B. Lee  
Aeronautical Research Scientist

Approved:



Joseph A. Shortal

Chief of Pilotless Aircraft Research Division

lsm

#### REFERENCES

1. Soderberg, L. R., Woodis, W. R., and Edgar, J. M.: Theoretical Considerations and Preliminary Design of a Dynamically Similar Model for Drop Tests of the AVCO Booster. Beech Aerodynamic Note 125, Beech Aircraft Corp., Apr. 11, 1956.
2. Soderberg, L. R., Woodis, W. R., and Edgar, J. M.: Similarity Relationships and Design Specifications of a 1/30 Scale Model of the AVCO Booster-Vehicle for Drop Tests in the NACA Pre-Flight Jet. Beech Aerodynamic Report 527, Beech Aircraft Corp., May 21, 1956.



TABLE I

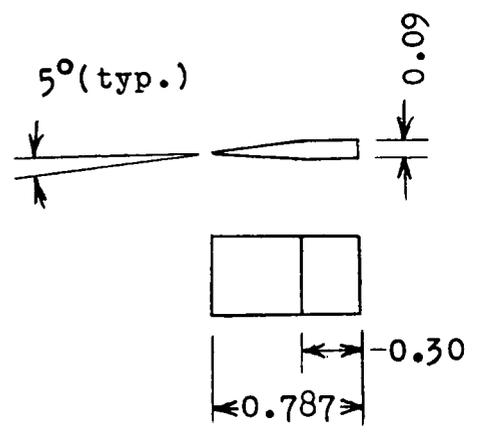
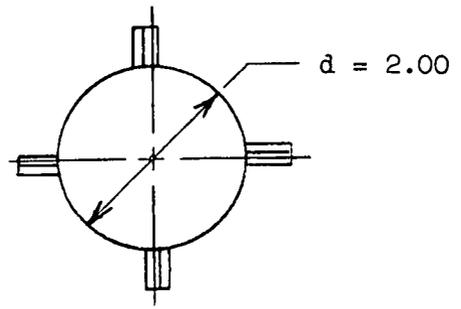
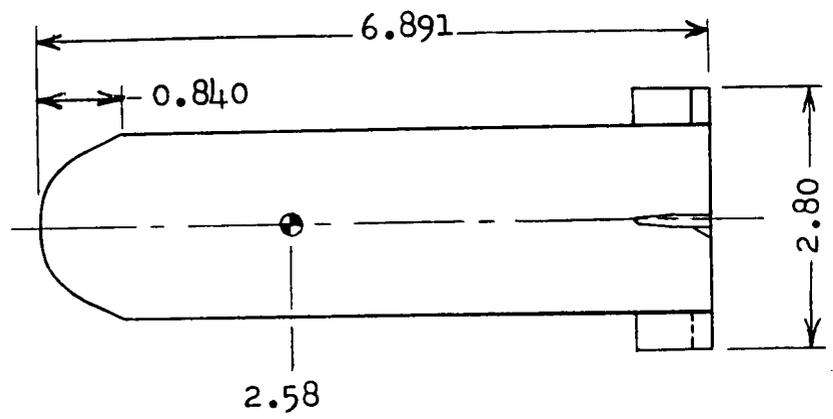
## TEST DATA

Test	Mach Number	$a_M$ (initial), g unit	$h_a$ (initial), ft	$W_s$ , lb	$I_y, M$ , lb/in. <sup>2</sup>	$\alpha_w$ , deg	$\Delta t$ , millisec	$q_0$ , lb/sq ft	$T_s$ , °R	Remarks
1	0.93	29.5	50,500	1.801	9.200	12	4	1,304	482	Original test of light model
2	.93	29.5	50,500	1.784	9.038	12	4	1,302	466	Repeat of test 1
3	.93	32.0	52,000	1.799	9.500	6	4	1,307	481	Effect of wing $\alpha_w$
4	.93	27.0	48,500	1.804	9.369	12	4	1,247	485	Ring encircling nose of store
5	.64	23.2	45,500	1.788	9.296	12	4	613	505	Mach number effect
6	.93	----	-11,800	4.246	23.427	12	8	1,318	471	Heavy model

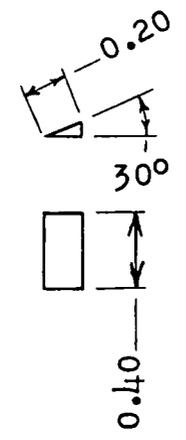
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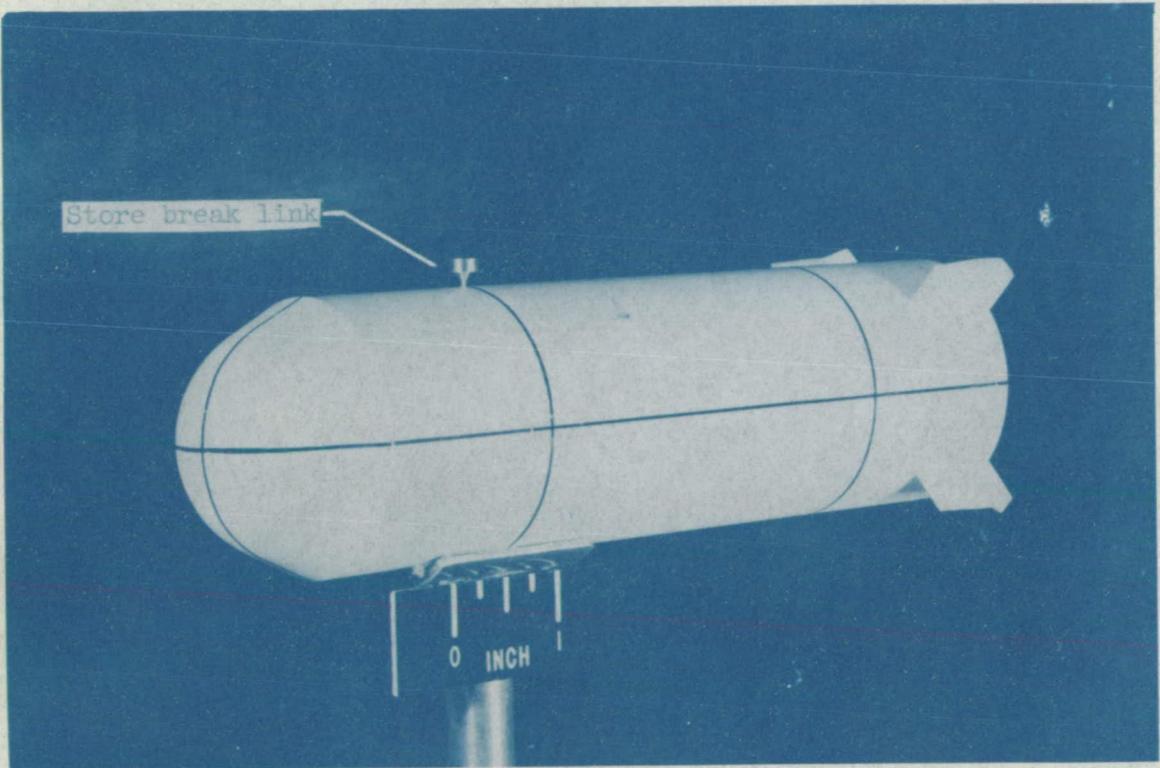


Fins



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Figure 1.- Sketch of 1/30-scale AVCO booster vehicle. (All dimensions are in inches.)



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Figure 2.- Photograph of 1/30-scale AVCO booster vehicle.

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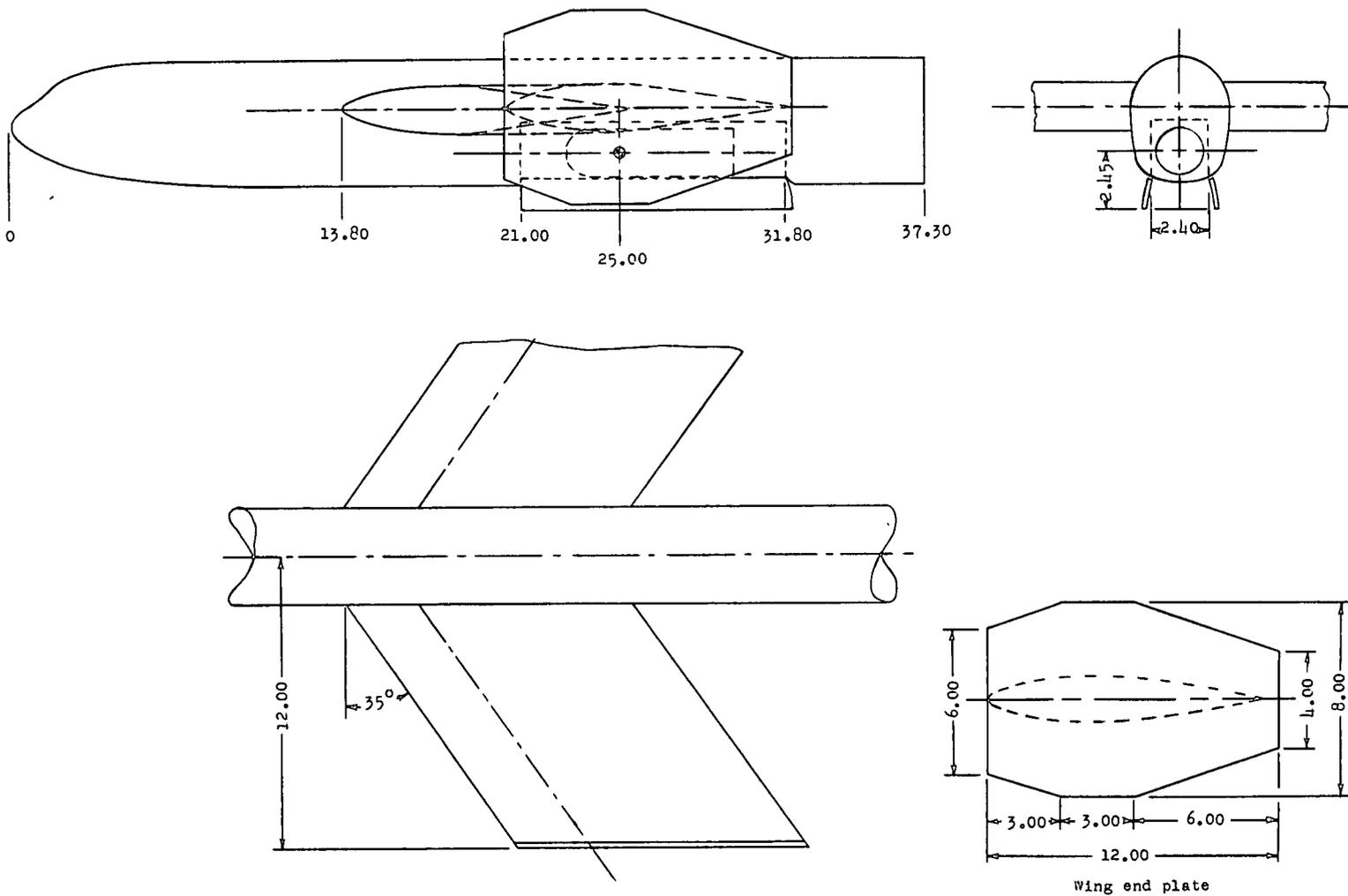
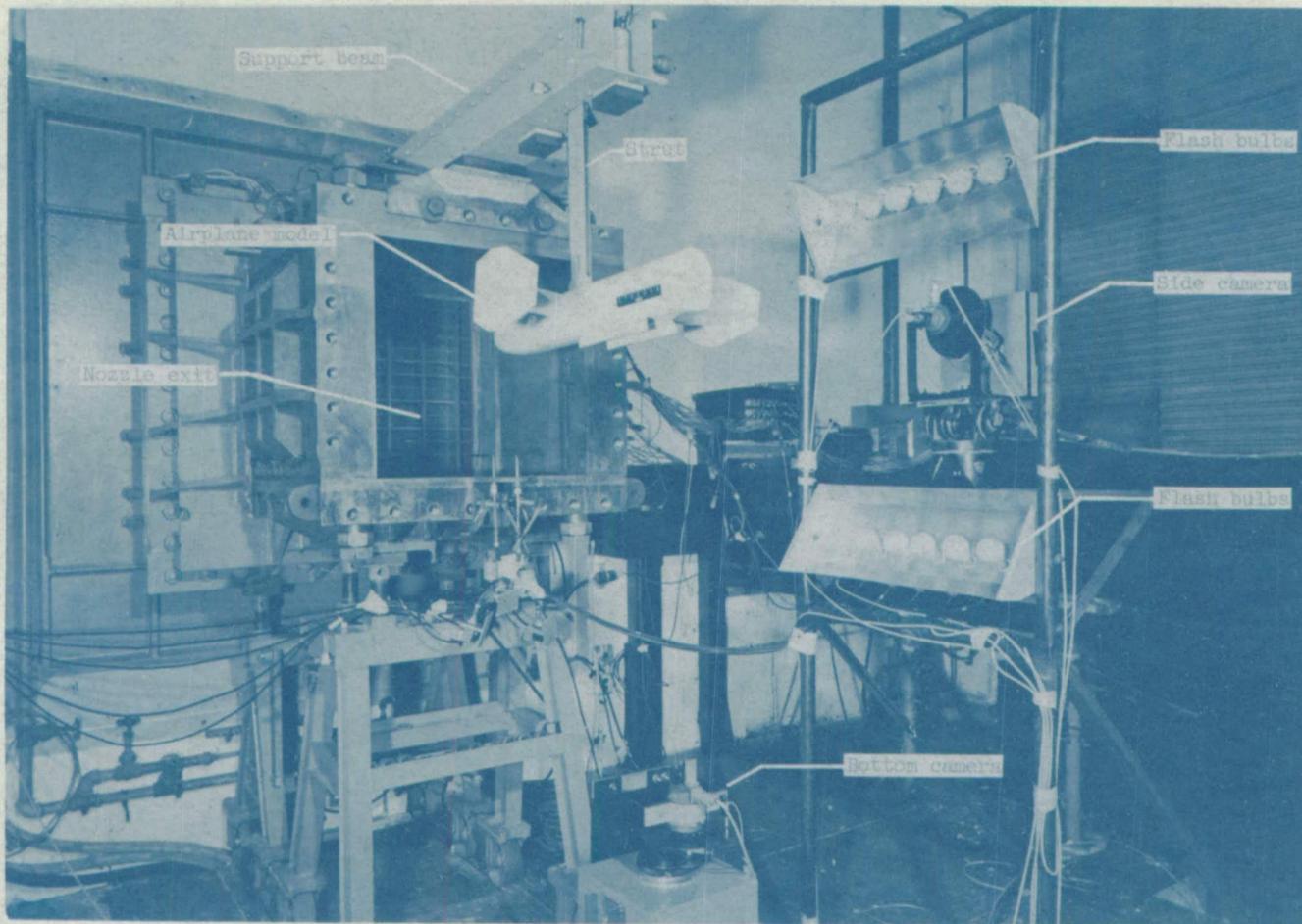


Figure 3.- Sketch of 1/30-scale B-52 airplane and AVCO booster vehicle test model. (All dimensions are in inches.)

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Figure 4.- Photograph of model installation in 27- by 27-inch preflight jet at Wallops Island, Va.

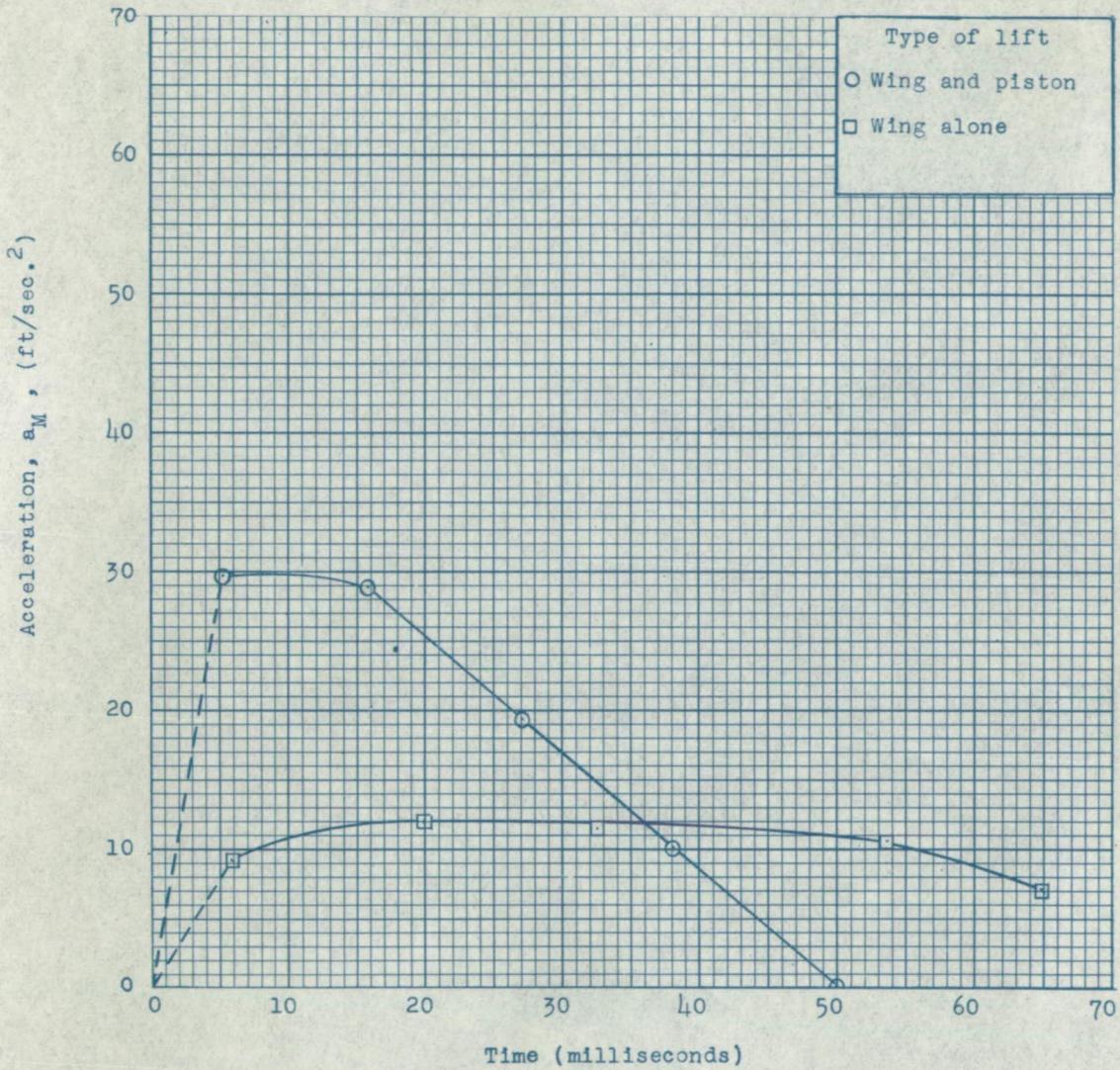
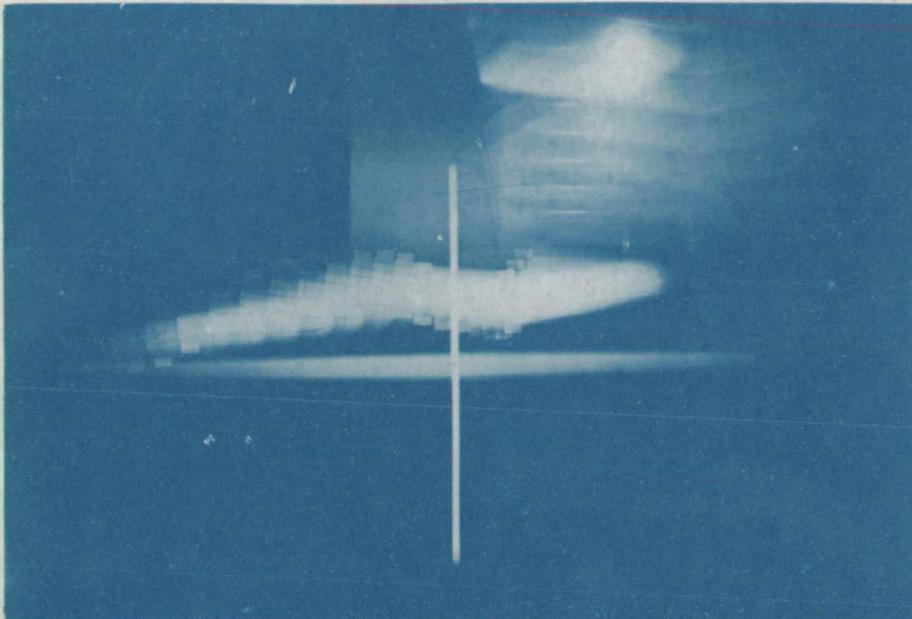
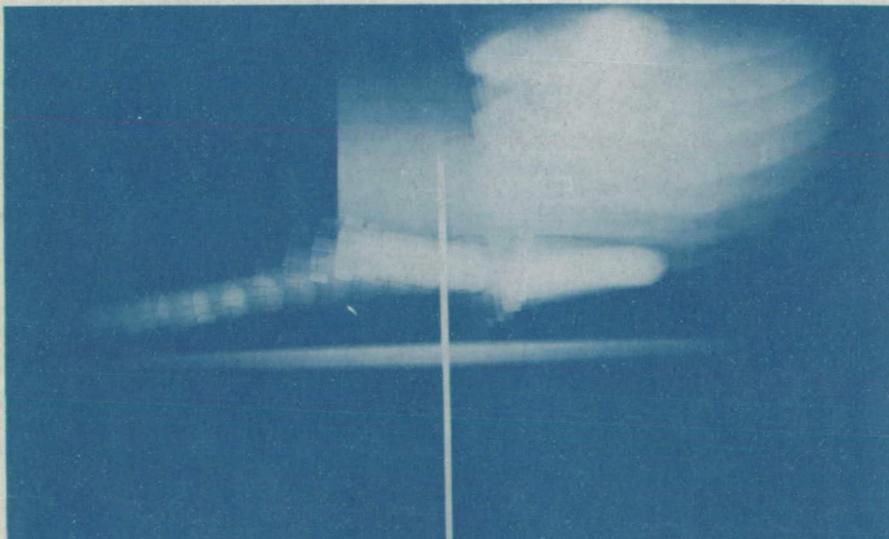


Figure 5.- Typical airplane-model acceleration from accelerometer.



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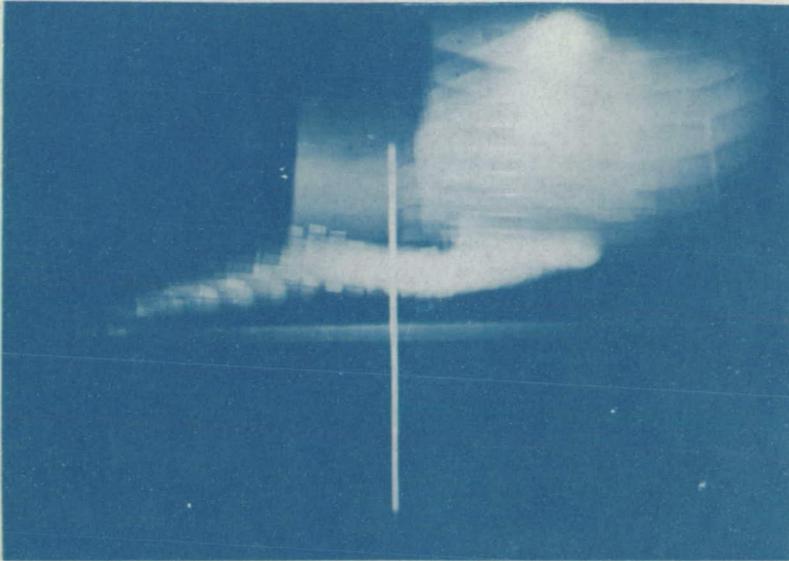
(a) Test 1. Light model;  $M_0 = 0.93$ ;  $h_p = 50,000$  feet;  $\alpha_w = 12^\circ$ .



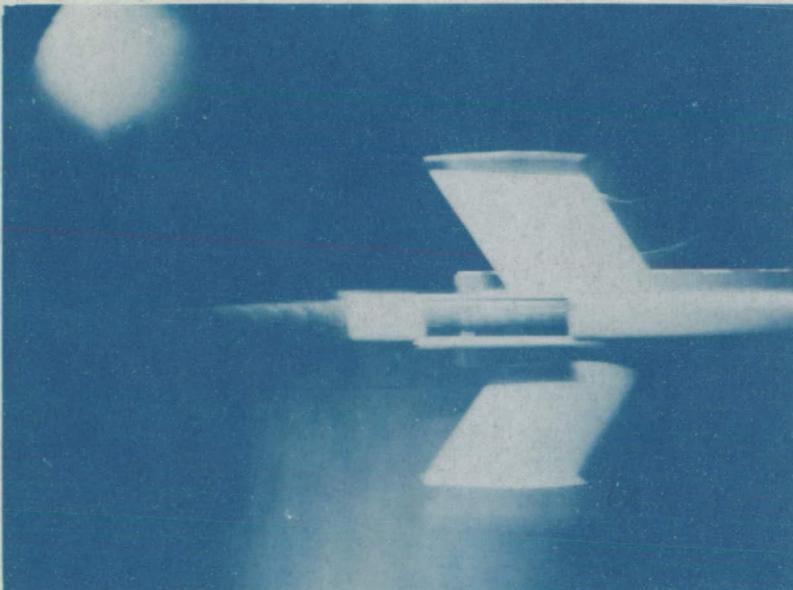
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(b) Test 2. Repeat of test 1.

Figure 6.- Stroboscopic photographs of the store release tests.



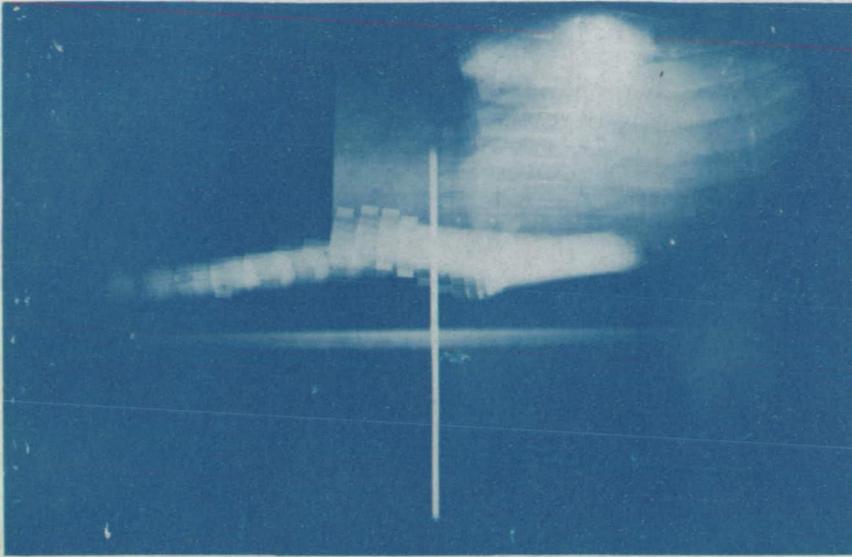
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L-95818

(c) Test 3. Light model;  $M_0 = 0.93$ ;  $h_p = 50,000$  feet;  $\alpha_w = 6^\circ$ .

Figure 6.- Continued.



L-95819

(d) Test 4. Light model with wire ring encircling nose;  $M_0 = 0.93$ ;  
 $h_p = 50,000$  feet;  $\alpha_w = 12^\circ$ .



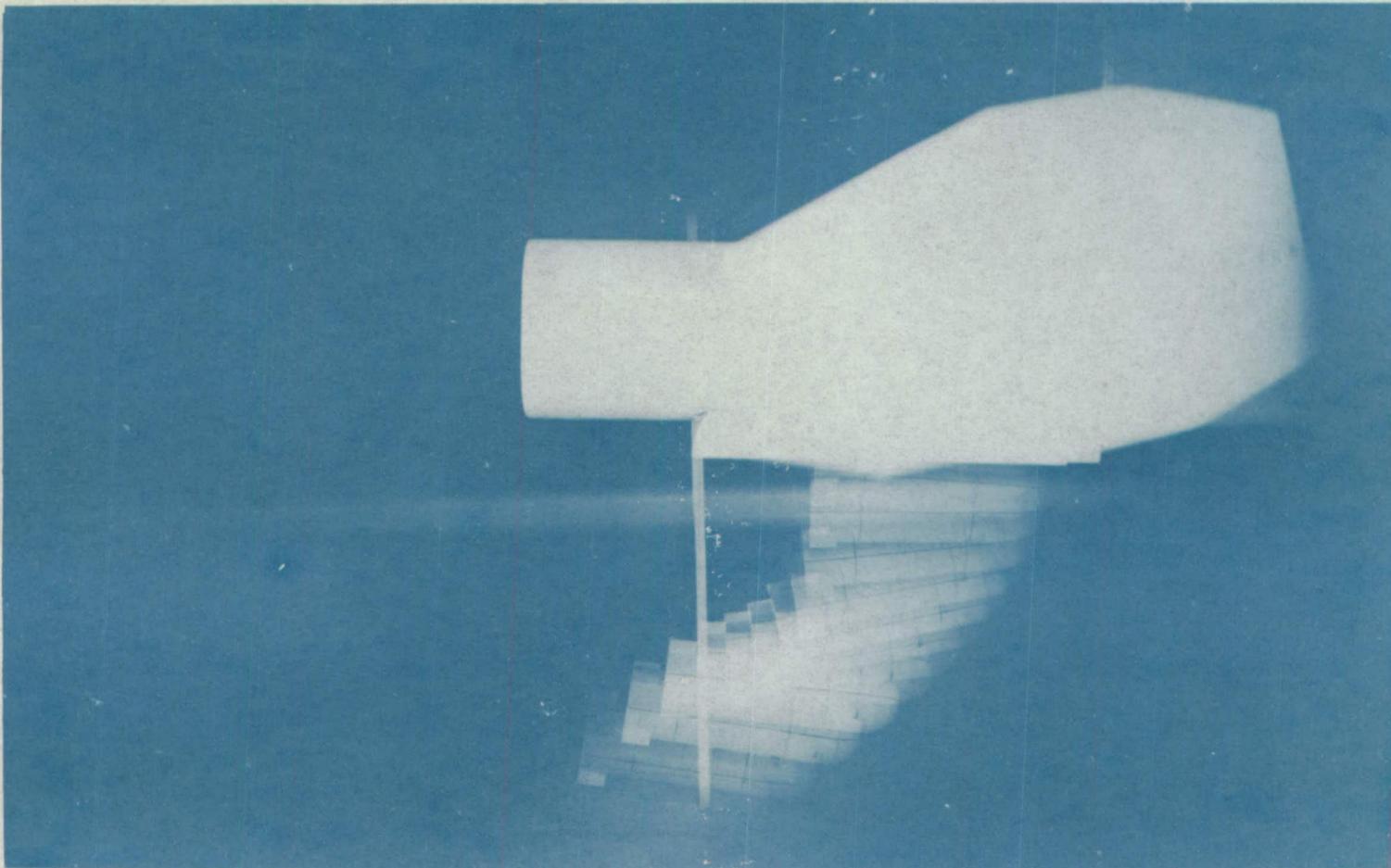
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(e) Test 5. Light model;  $M_0 = 0.64$ ;  $h_p = 50,000$  feet;  $\alpha_w = 12^\circ$ .

Figure 6.- Continued.



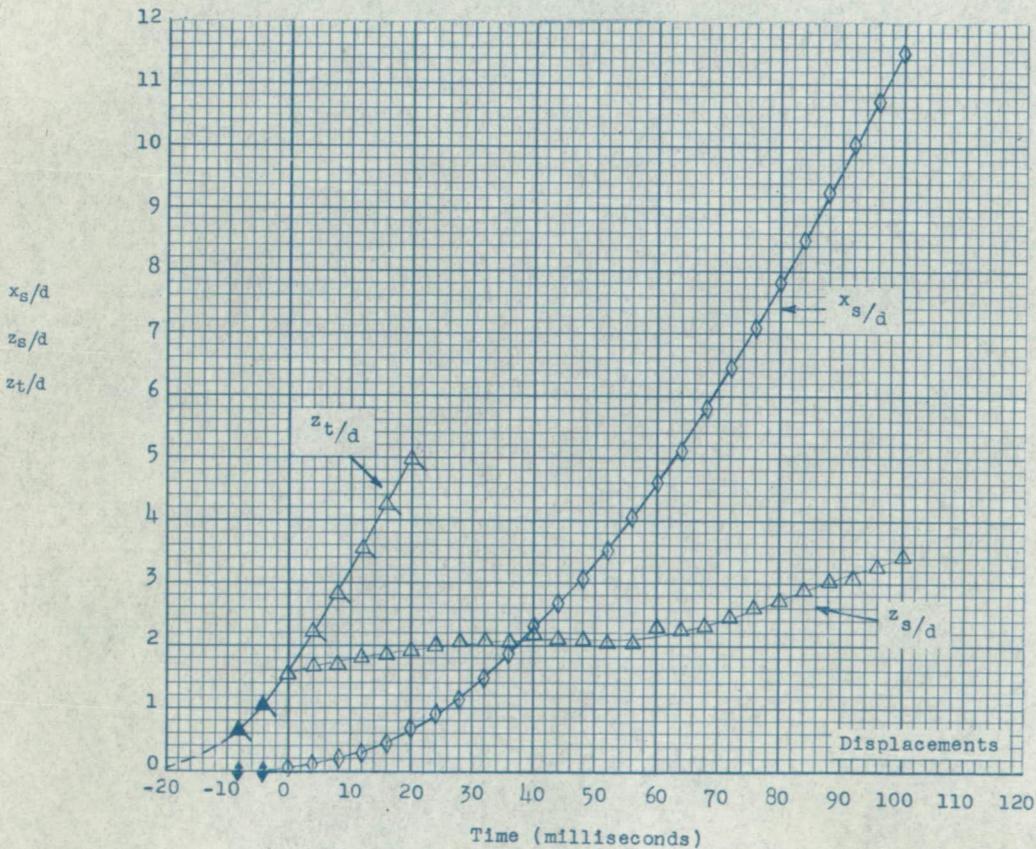
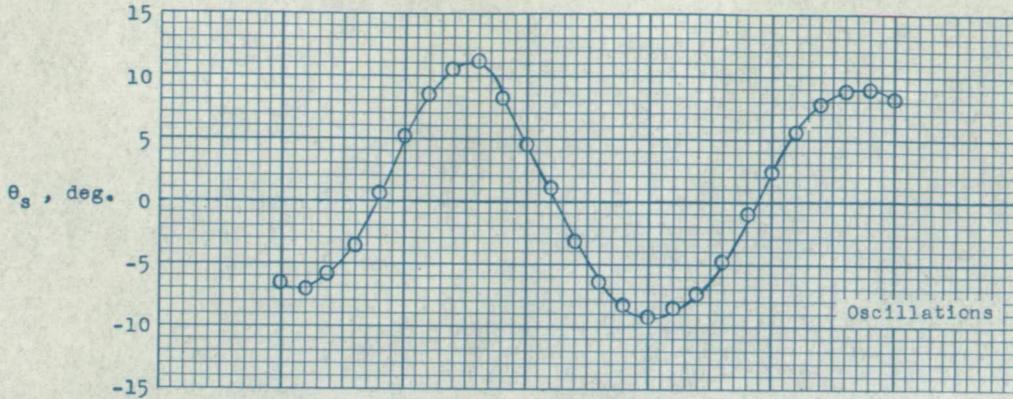
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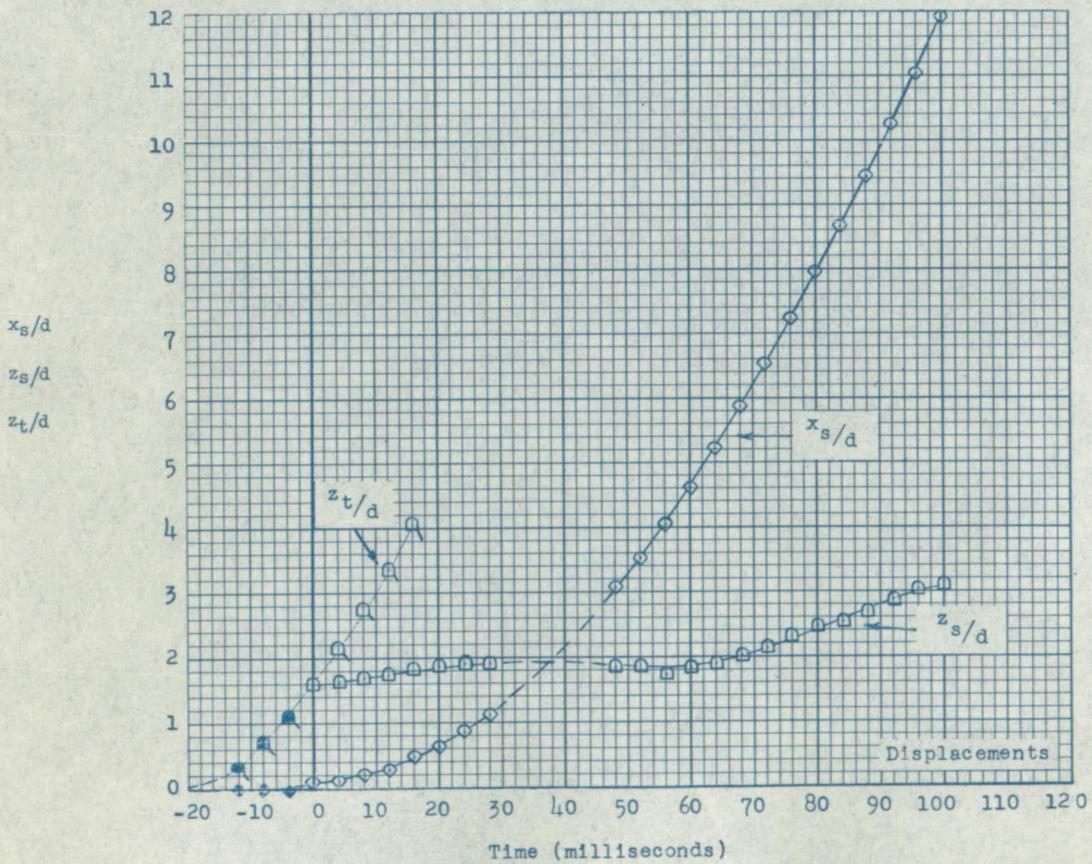
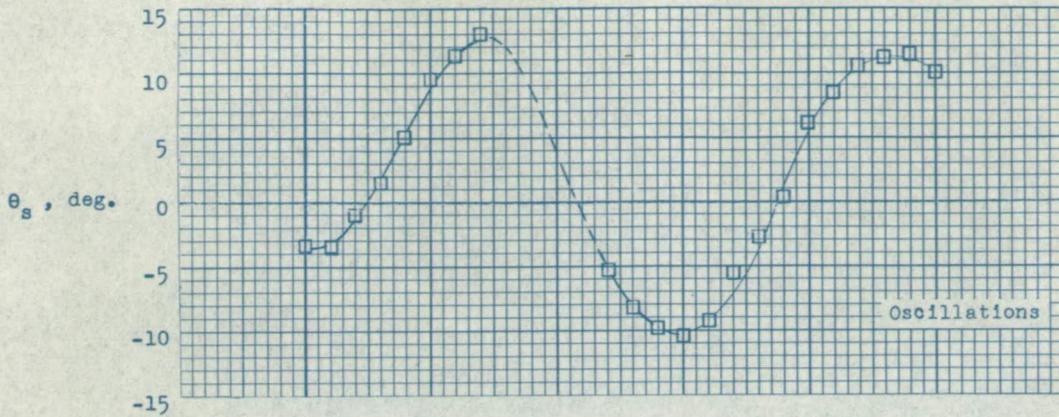
(f) Test 6. Heavy model;  $M_0 = 0.93$ ;  $h_p = -11,800$  feet;  $\alpha_w = 12^\circ$ .

Figure 6.- Concluded.



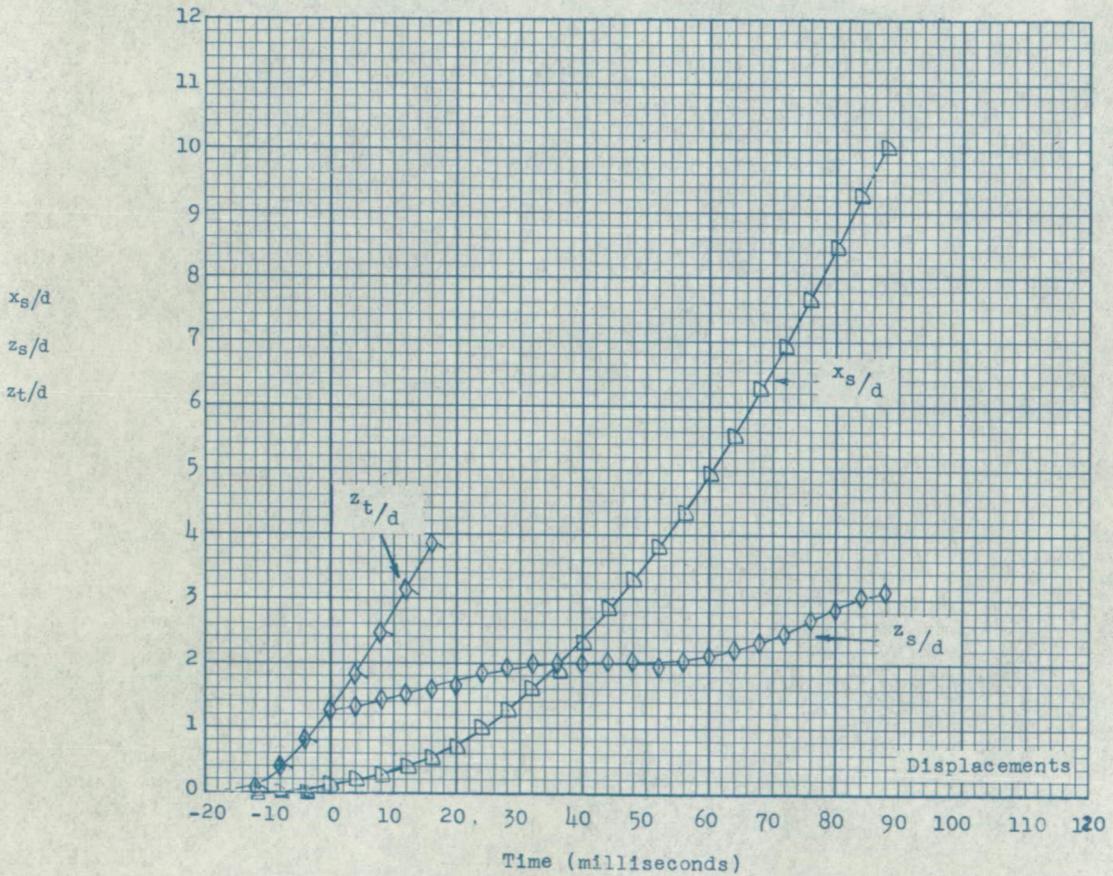
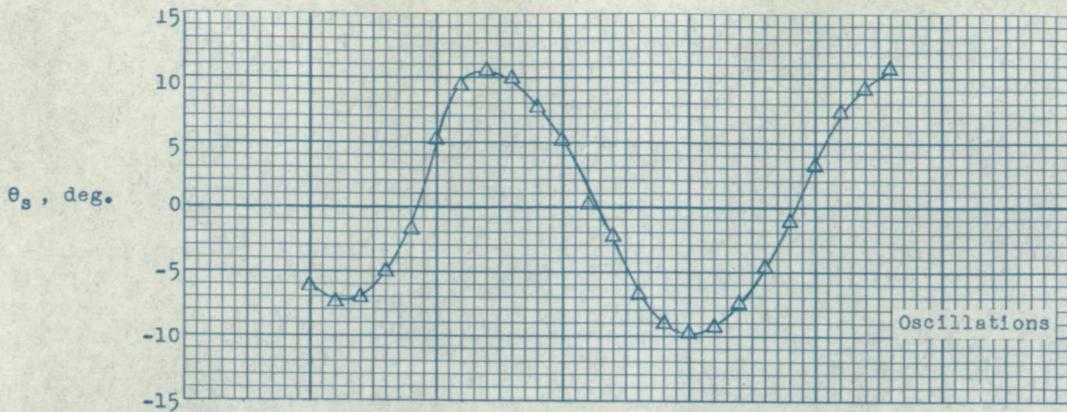
(a) Test 1. Light model;  $M_0 = 0.93$ ;  $h_p = 50,000$  feet;  $\alpha_w = 12^\circ$ .

Figure 7.- Time-history plots of store oscillations and of store and fuselage displacements.



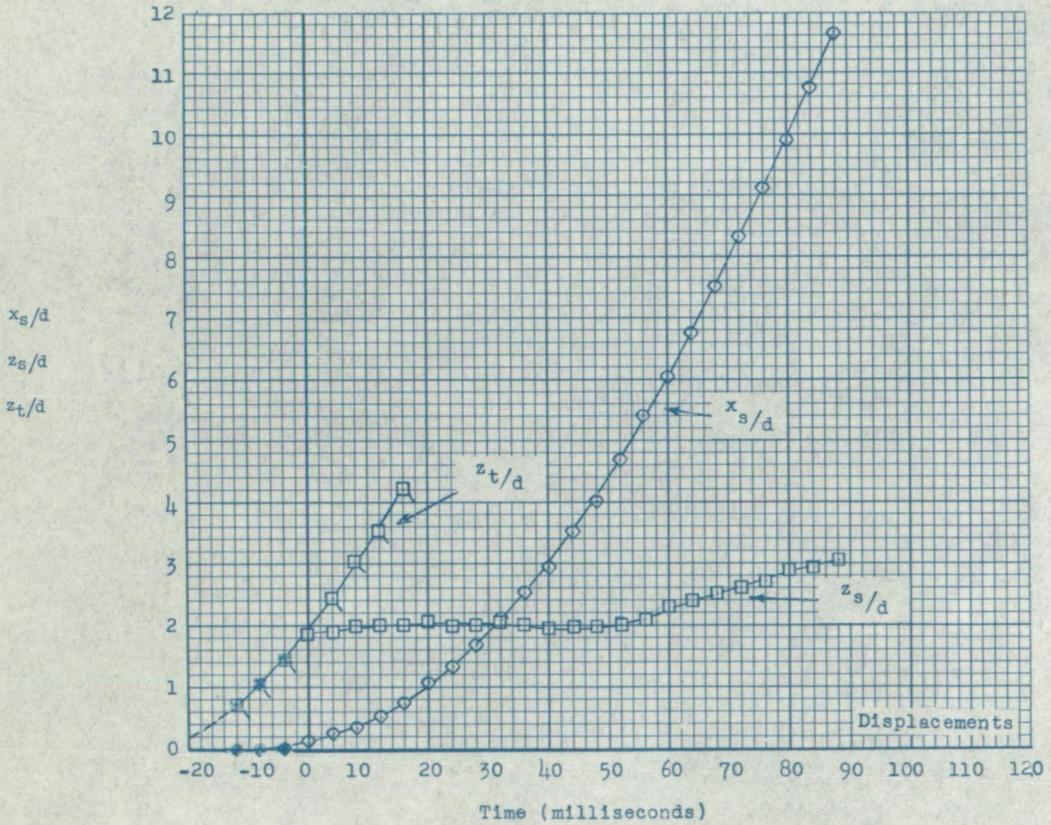
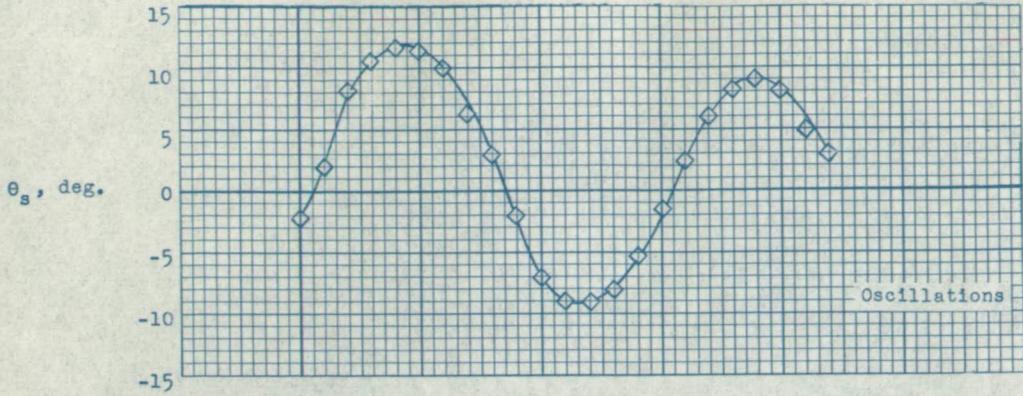
(b) Test 2. Repeat of test 1.

Figure 7.- Continued.



(c) Test 3. Light model;  $M_0 = 0.93$ ;  $h_p = 50,000$  feet;  $\alpha_w = 6^\circ$ .

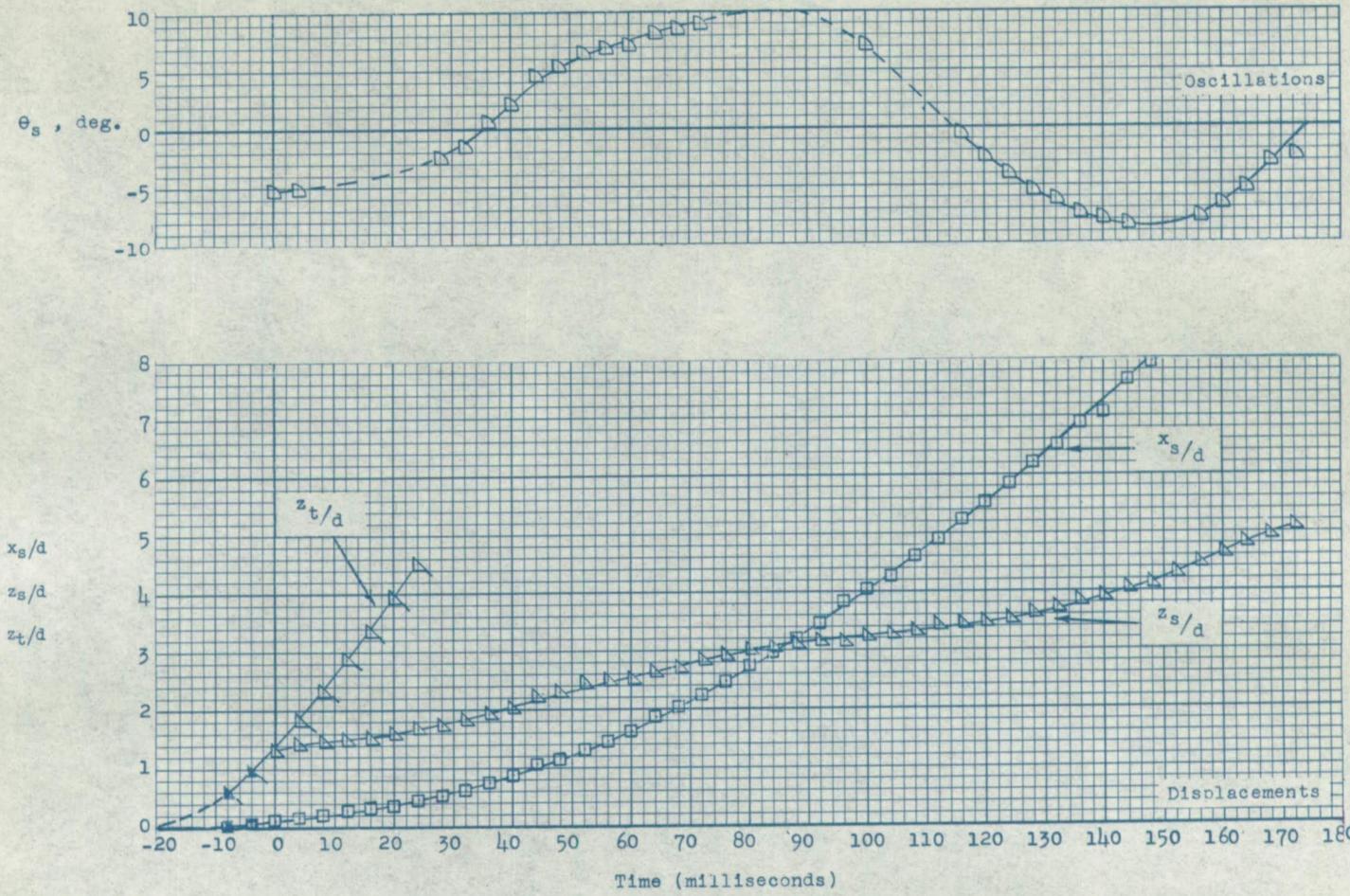
Figure 7.- Continued.



(d) Test 4. Light model with wire ring encircling nose;  $M_0 = 0.93$ ;  
 $h_p = 50,000$  feet;  $\alpha_w = 12^\circ$ .

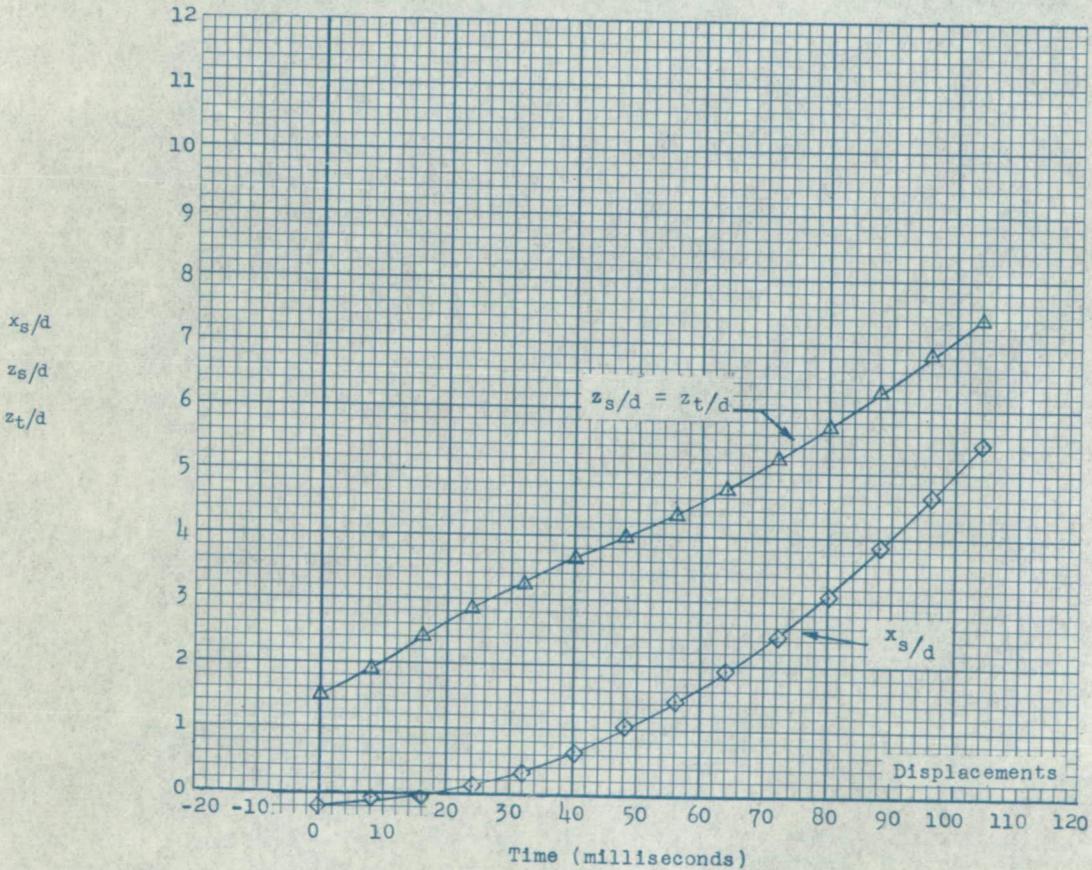
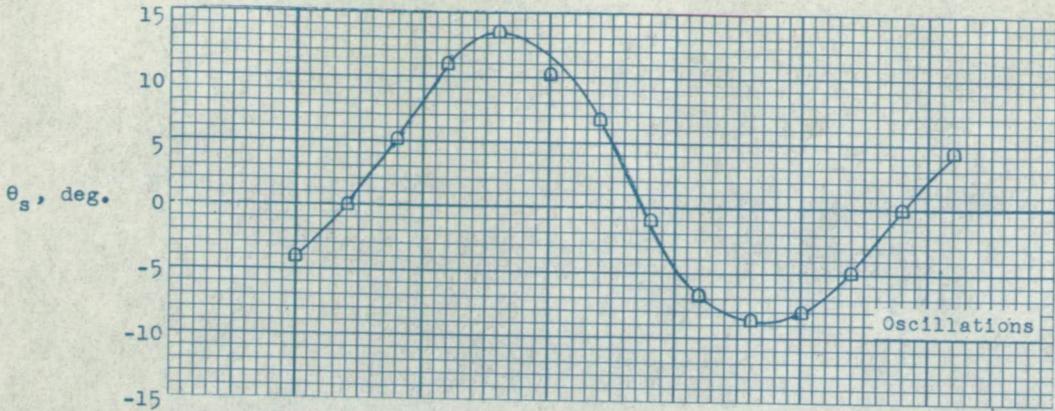
Figure 7.- Continued.

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(e) Test 5. Light model;  $M_0 = 0.64$ ;  $h_p = 50,000$  feet;  $\alpha_w = 12^\circ$ .

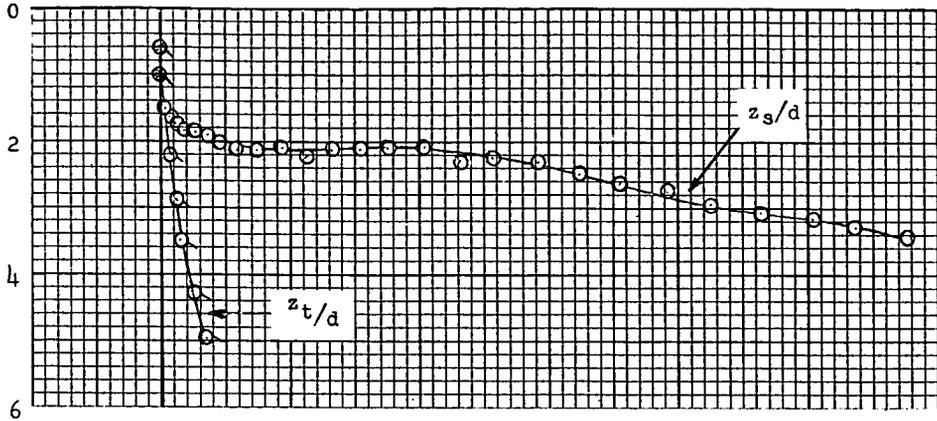
Figure 7.- Continued.



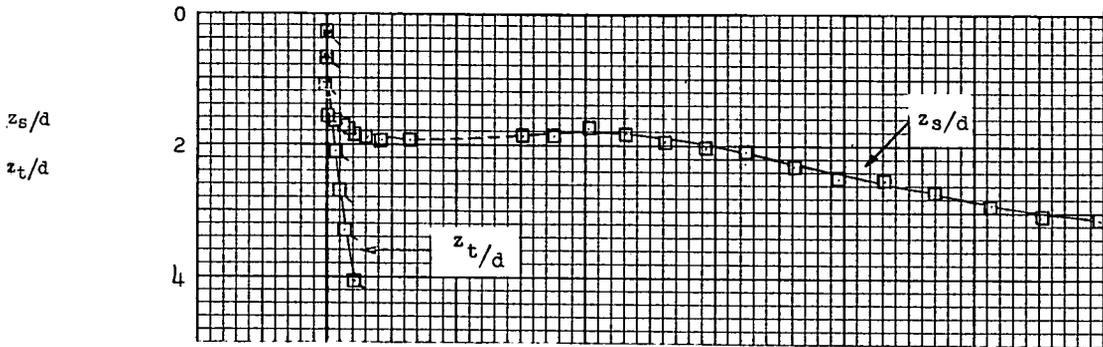
(f) Test 6. Heavy model;  $M_0 = 0.93$ ;  $h_p = -11,800$  feet;  $\alpha_w = 12^\circ$ .

Figure 7.- Concluded.

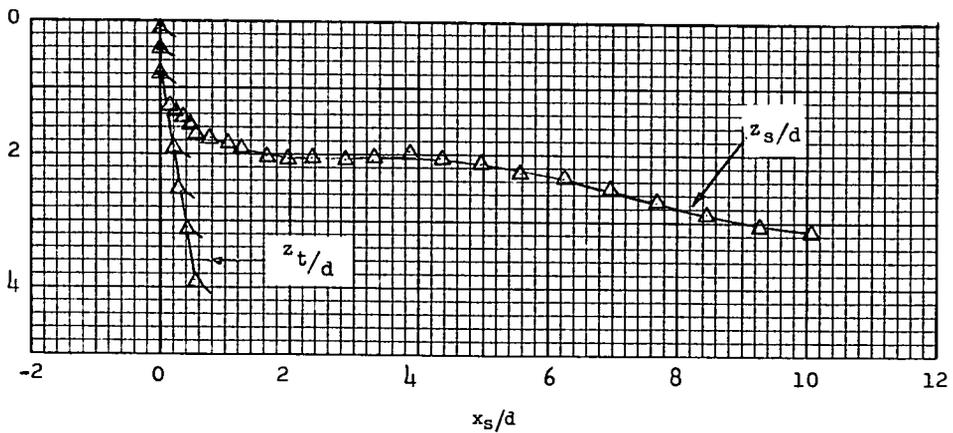
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(a) Test 1. Light model;  $M_0 = 0.93$ ;  $h_p = 50,000$  feet;  $\alpha_w = 12^\circ$ .

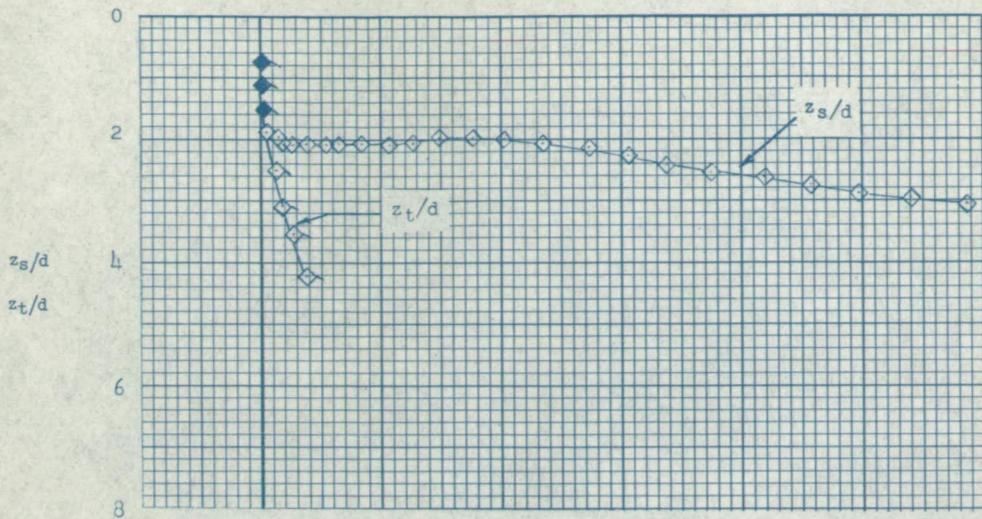


(b) Test 2. Repeat of test 1.

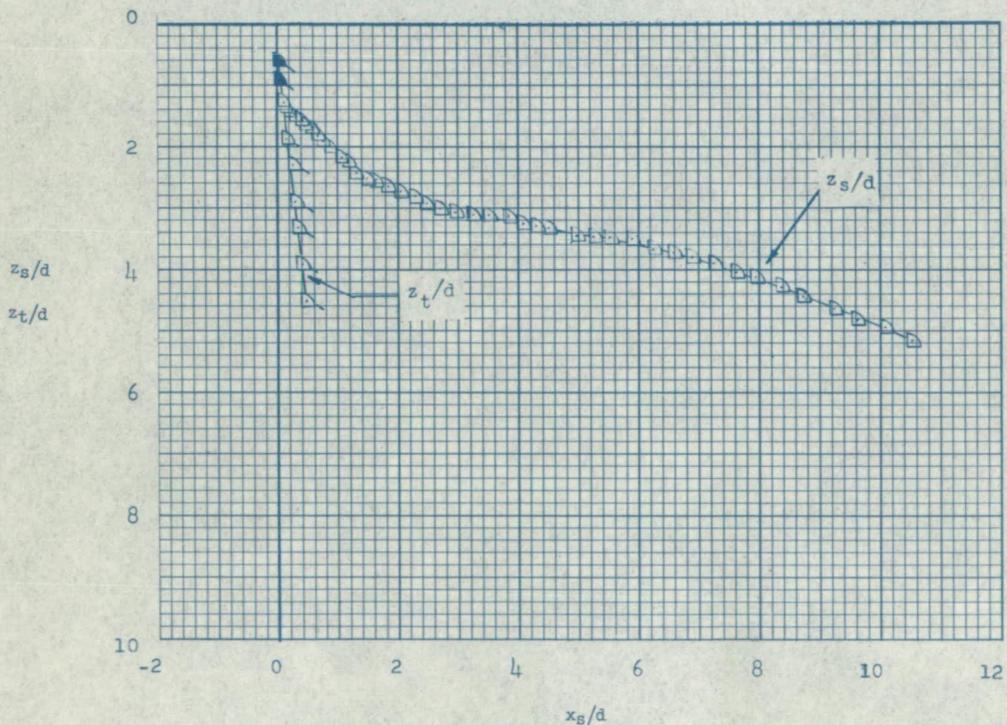


(c) Test 3. Light model;  $M_0 = 0.93$ ;  $h_p = 50,000$  feet;  $\alpha_w = 6^\circ$ .

Figure 8.- Store trajectories.



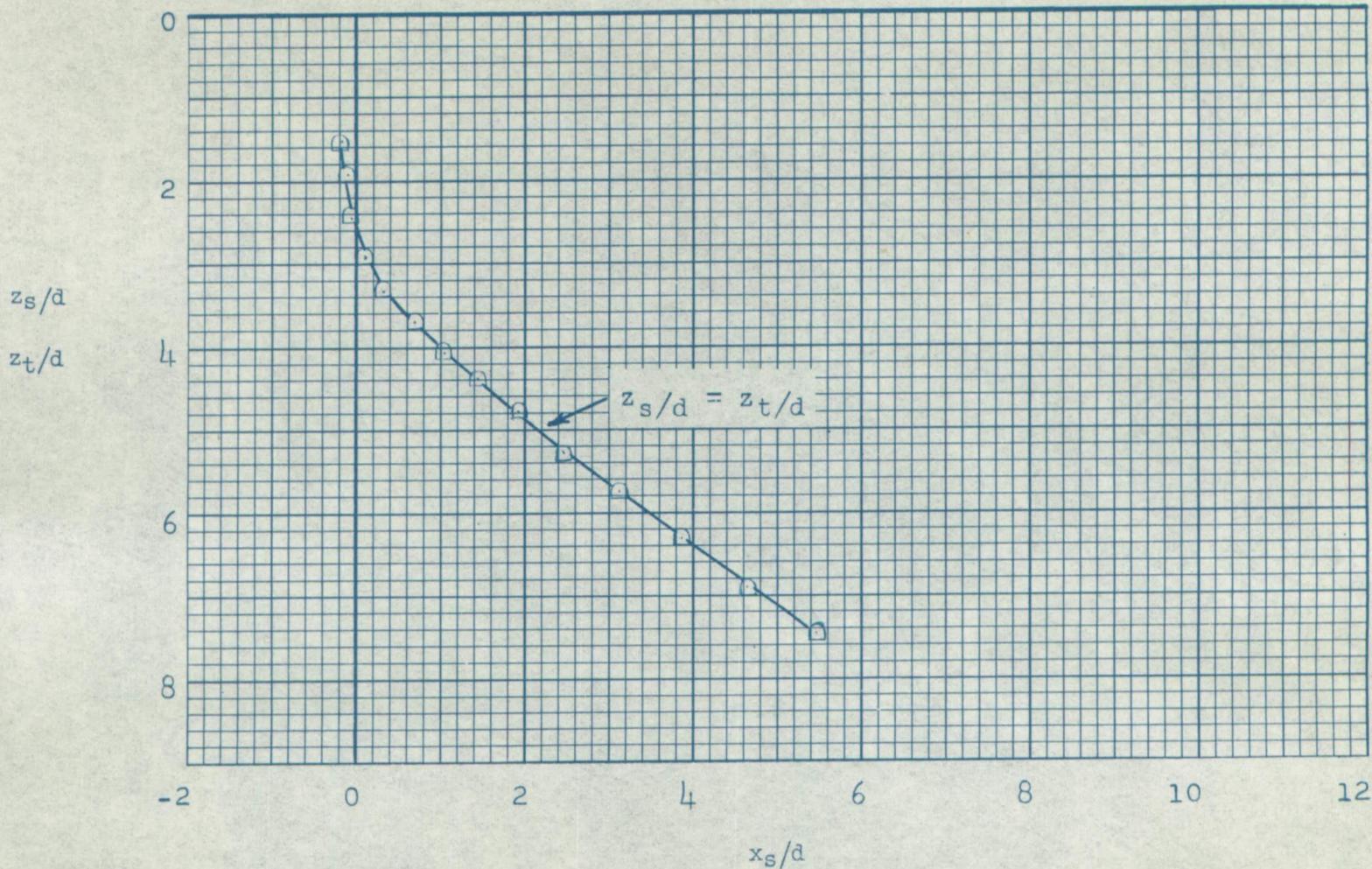
(d) Test 4. Light model with wire ring encircling nose;  $M_0 = 0.93$ ;  $h_p = 50,000$  feet;  $\alpha_w = 12^\circ$ .



(e) Test 5. Light model;  $M_0 = 0.64$ ;  $h_p = 50,000$  feet;  $\alpha_w = 12^\circ$ .

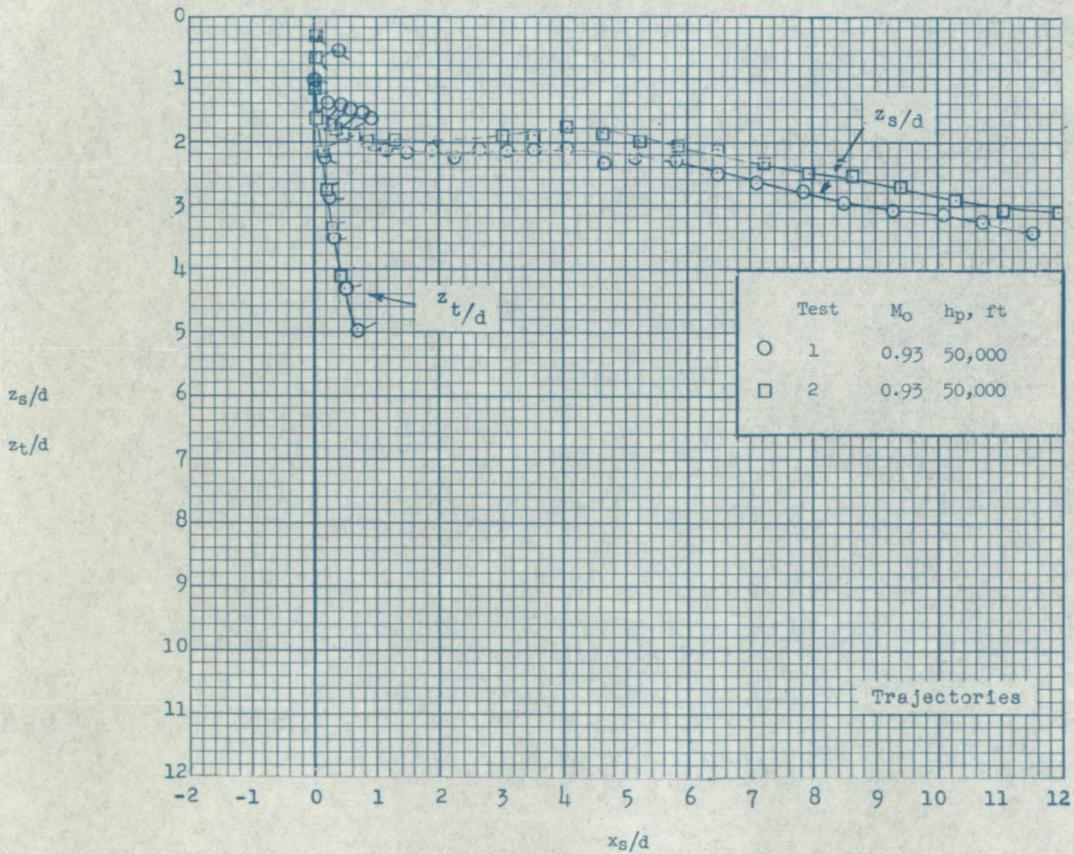
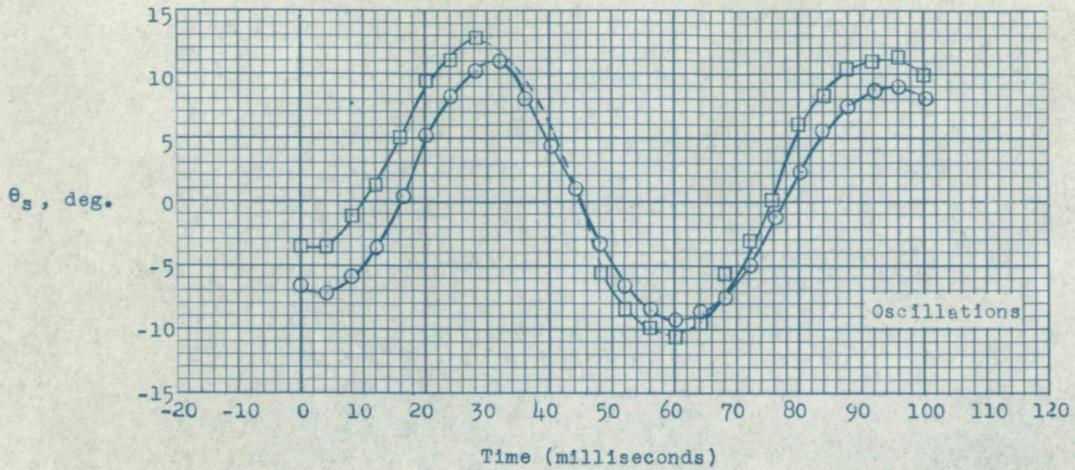
Figure 8.- Continued.

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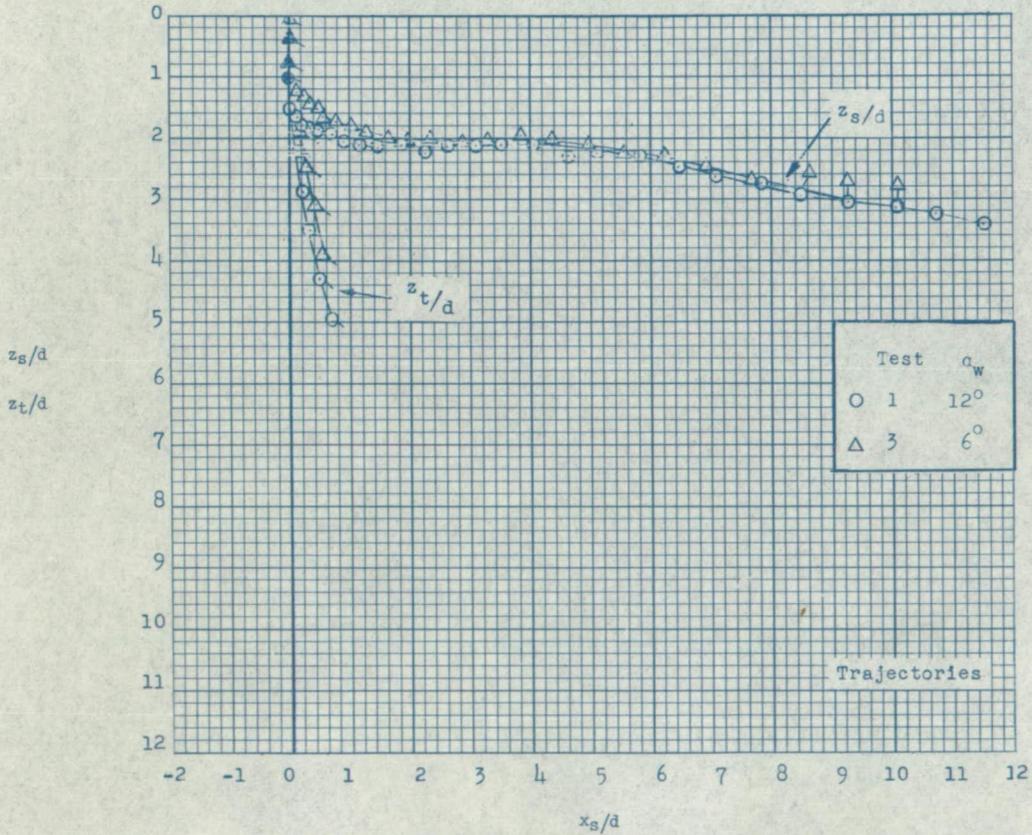
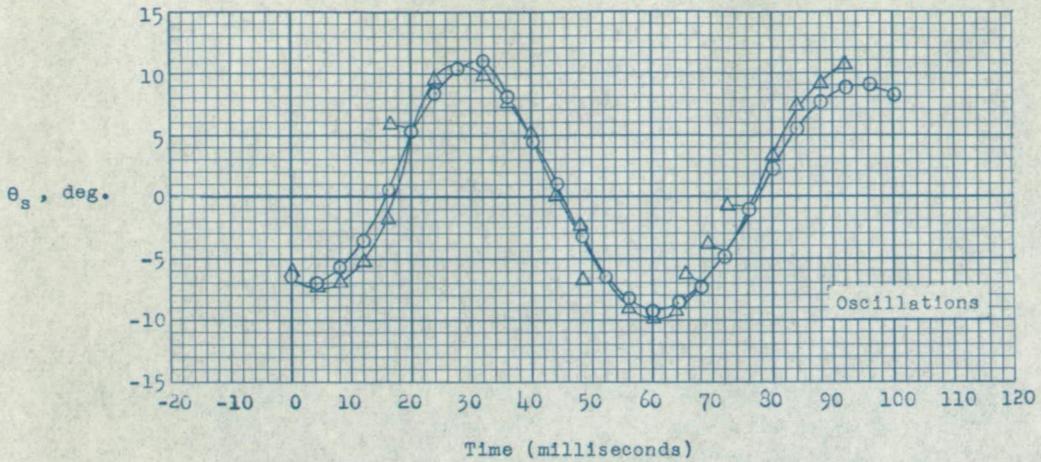
(f) Test 6. Heavy model;  $M_0 = 0.93$ ;  $h_p = -11,800$  feet;  $\alpha_w = 12^\circ$ .

Figure 8.- Concluded.



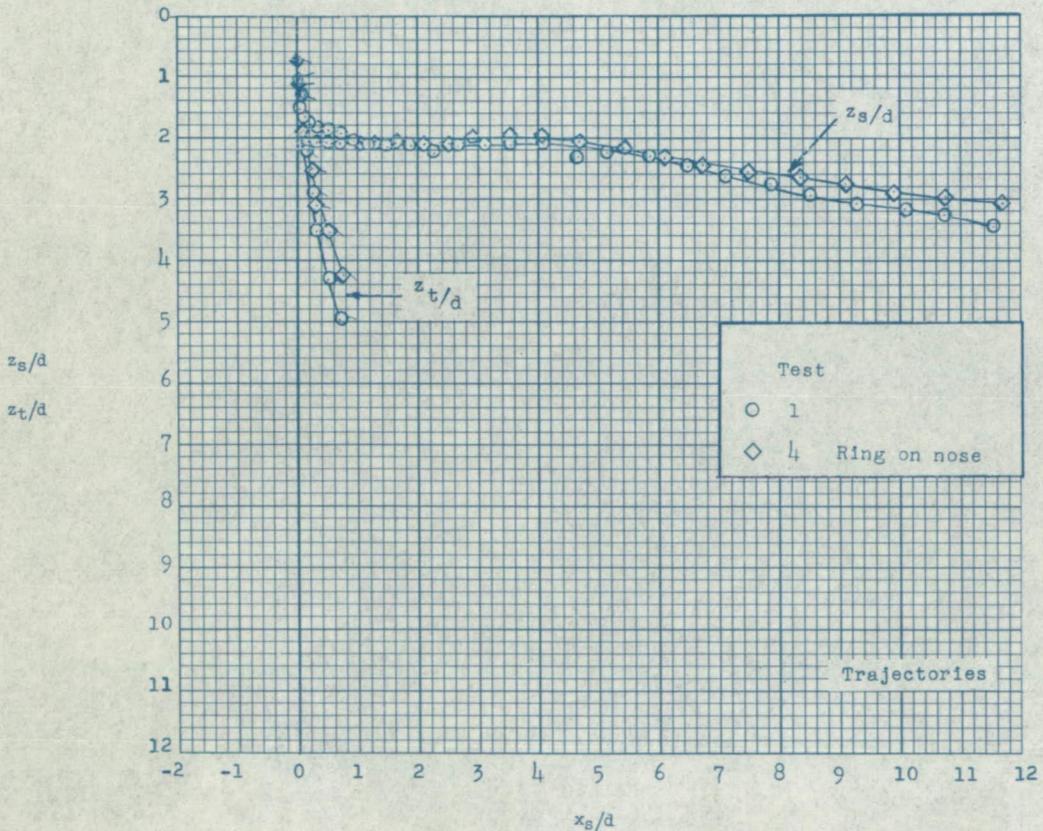
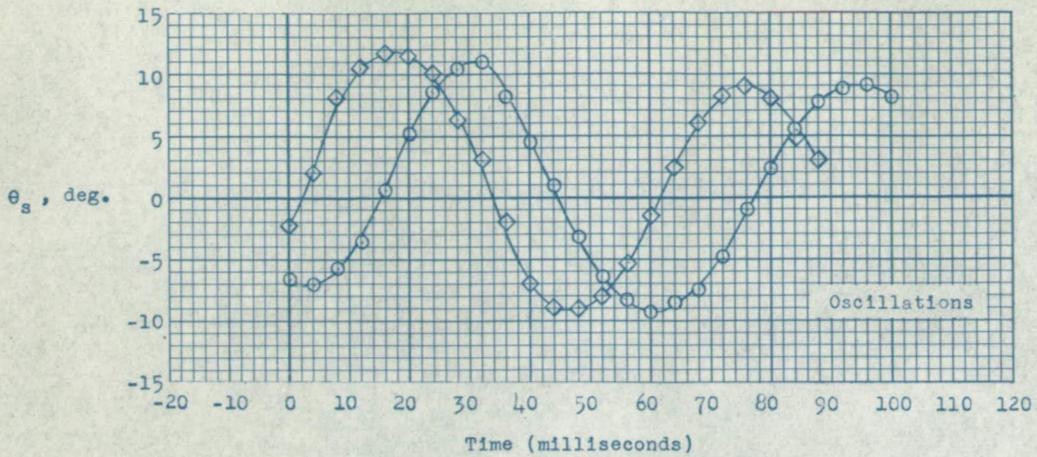
(a) Repeat tests of light models.

Figure 9.- Comparisons of store oscillations and trajectories for changes in test conditions.



(b) Effect of change in  $\alpha_w$  at  $M_0 = 0.93$  and  $h_p = 50,000$  feet on characteristics of light models.

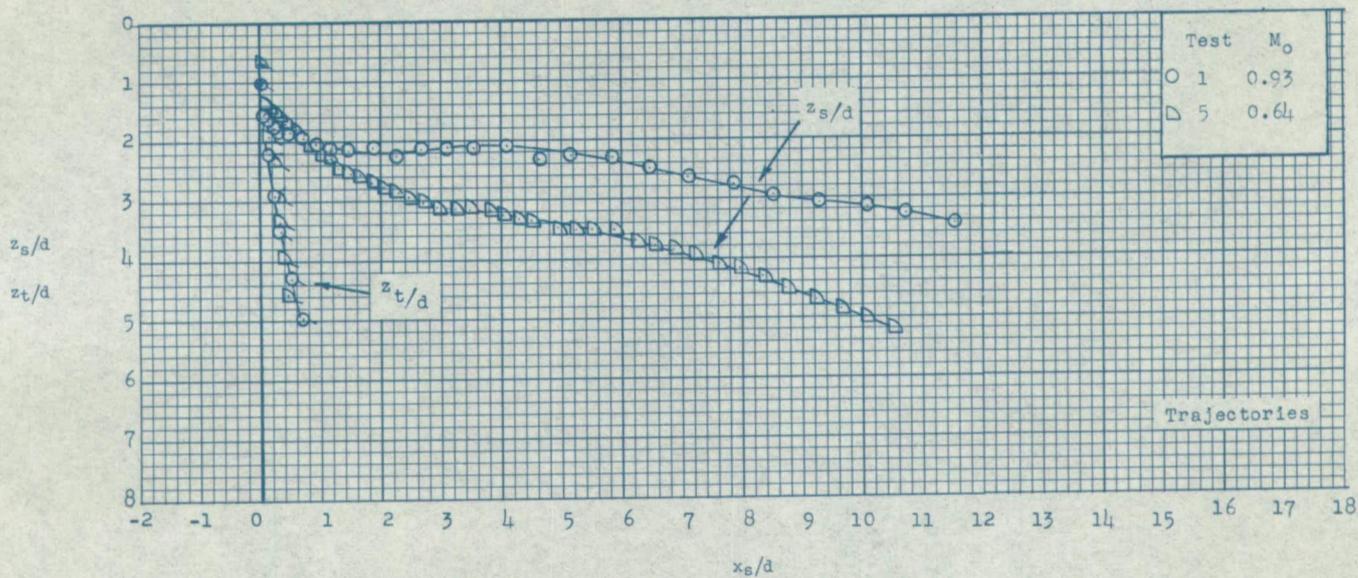
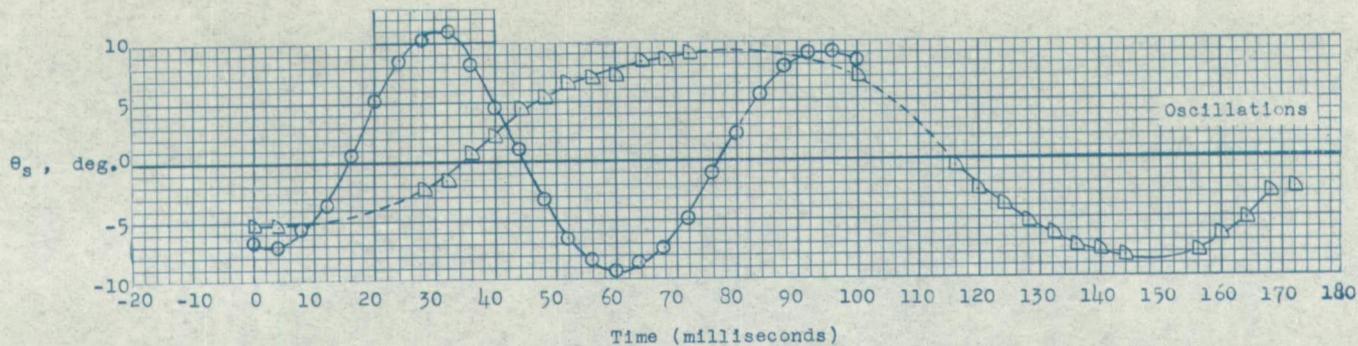
Figure 9.- Continued.



(c) Effect of ring encircling nose of store with light model of  $M_0 = 0.93$ ;  $h_p = 50,000$  feet; and  $\alpha_w = 12^\circ$ .

Figure 9.- Continued.

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(d) Decrease in Mach number at  $h_p = 50,000$  feet.

Figure 9.- Concluded.

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## ABSTRACT

An investigation of the release characteristics of a dynamically scaled booster vehicle from a 1/30-scale simulated bomb bay of a B-52 airplane was conducted in the 27- by 27-inch preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va., at Mach numbers of 0.64 and 0.93. Similarity was obtained by scaling the model by the light-model method and accelerating the mother ship at the instant of release. A test drop was also made of a model for which dynamic similarity was obtained by the heavy-model method. The purpose of the investigation was to determine whether the AVCO booster vehicle could be free-dropped from the bomb bay of a B-52 aircraft at high altitudes and high subsonic Mach numbers.

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