RESEARCH MEMORANDUM

A WIND-TUNNEL INVESTIGATION OF BOMB RELEASE AT A MACH NUMBER OF 1.62

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

A model bomb-release investigation has been conducted in the Langley 9-inch supersonic tunnel at a Mach number of 1.62 to determine what first-order interference effects are involved in making releases at supersonic speeds and, in some cases, to ascertain what modifications might be made to obtain near-level drops. Four model bomb, or store, configurations were utilized, one of which was a 1/70-scale model of the 5,000-pound Douglas Aircraft Co., Inc., store shape. Releases were made from seven fuselage—bomb-bay combinations and from four positions at the 80-percent-semispan station of an untapered, 30° swept wing. The simulated prototype altitudes varied from 40,000 feet to 10,000 feet at test Reynolds numbers of from about 0.1×10^6 to about 0.4×10^6, respectively, based on bomb length.

The results of these tests indicate that the interference effects of the fuselage or wing-pylon upon the bomb release are, in most cases, adverse. It is possible, however, to obtain near-level releases through the proper selection of bomb—bomb-bay combination for releases made from a fuselage or through the correct positioning of the bomb and pylon for releases made from a wing. In general, an increase in altitude appears beneficial to the release characteristics.

INTRODUCTION

The problem of obtaining successful bomb releases at supersonic speeds is at present of primary concern. The bomb release must be accomplished in a manner such that the bomb load neither strikes nor endangers the aircraft or its equipment; also, because of possible instrumentation within the bomb, the bomb must not undergo large accelerations or decelerations and, consequently, no large changes in angles of pitch or yaw. Also, the release characteristics must have no large effects upon the bomb trajectory. It becomes apparent, then, that the interference factors which might cause the bombs to diverge from a near-level attitude during release must be minimized.

Although several bomb-release investigations have been made at subsonic speeds (for instance, see refs. 1 and 2), there is a definite scarcity of such information at supersonic speeds. In order to shed some light on the supersonic bomb-release problem, drop tests have been made in the Langley 9-inch supersonic tunnel at a Mach number of 1.62 using four bomb configurations released from several bomb bays and from several pylons beneath a swept wing. The tests were made at simulated altitudes of from 10,000 feet to 40,000 feet at Reynolds numbers of from 0.1×10^6 to 0.4×10^6 based on the length of the bomb. The tests were of an exploratory nature to determine what first-order interference effects might be involved and to ascertain, in some cases, what modifications might be made to obtain near-level releases.

SYMBOLS

b	wing span
C_D	drag coefficient, $\frac{\text{Drag}}{ql^2}$
d	maximum body diameter
q	dynamic pressure
l	representative length
M	Mach number
w	average bomb mass density
x/l	horizontal distance from the 50-percent-wing-chord point to the bomb center of gravity as a fraction of the bomb length
z/l	vertical distance between the lowermost portion of the bottom wing surface and the uppermost portion of the bomb body as a fraction of the bomb length
α	fuselage angle of attack
i_B	bomb angle of incidence

SIMILARITY RELATION

For most dynamic testing, near-complete simulation of prototype conditions is desirable. This becomes difficult in the cases where the tests are to be made in moderately small wind tunnels where models are limited in size, especially for supersonic testing where the prototype Mach number must be duplicated and, consequently, in many cases, the prototype velocity is approximated (see ref. 3). Therefore, for the present tests, simulation was limited to the ratio of bomb mass and dynamic pressure so that

$$\left(\frac{\text{Drag}}{\text{Gravity force}}\right)_{\text{model}} = \left(\frac{\text{Drag}}{\text{Gravity force}}\right)_{\text{prototype}}$$

This means that the path of the model center of gravity essentially duplicated the path of the prototype center of gravity for the releases where the bomb attitude was near-level, that is, where the upsetting lifts and moments were small.

This relation of drag to gravity can be put in the form,

$$\left(\frac{C_D q l^2}{w l^3}\right)_{\text{model}} = \left(\frac{C_D q l^2}{w l^3}\right)_{\text{prototype}}$$

and, by assuming $C_{D_{\text{model}}} = C_{D_{\text{prototype}}}$ (this assumption will be discussed later), then,

$$\left(\frac{q}{wl}\right)_{\text{model}} = \left(\frac{q}{wl}\right)_{\text{prototype}}$$

For the present test the prototype was assumed to be a 5,000-pound Douglas Aircraft Co., Inc., store which established $w_{\text{prototype}}$ and $l_{\text{prototype}}$. By assuming various altitudes, $q_{\text{prototype}}$ was established for this constant Mach number of 1.62. With regard to the model, the tunnel dimensions established l_{model}. In order to fulfill the similarity relation, the ratio $\left(\frac{q}{w}\right)_{\text{model}}$ had to be small; so the tunnel was operated at low stagnation pressures (thereby resulting in low tunnel dynamic pressures) and the models were constructed of lead. Variations in prototype altitude were simulated by changing the tunnel stagnation pressure. For a given simulated altitude, the tunnel dynamic pressure was the same for all models. Also, the shape of the trajectory for a bomb at one simulated altitude would be essentially the same as that for the same bomb configuration with a different bomb density and at a different simulated altitude.

Through the use of this similarity relation, the model Reynolds number was unavoidably low; therefore, force tests were made to ascertain the effects of the low Reynolds numbers upon the aerodynamic characteristics of these bomb configurations (see ref. 4). These results showed that, with the exception of bomb 4 (see fig. 1), there were only small changes in center-of-pressure position as a result of varying the Reynolds number from that of the bomb-drop tests to a value of about 10×10^6. Throughout this Reynolds number range, however, all bombs were statically stable about their centers of gravity. Also, at the Reynolds number of the drop tests, the sequence in which the static stability of the configurations increased was: bombs 4, 1, 2, and 3.

Also, presented in reference 4 are the drag coefficients of these bomb configurations as a function of Reynolds number. As would be expected, C_D increased with Reynolds number up to the Reynolds number for transition from a laminar to a turbulent boundary layer with little change beyond. This means that for the Reynolds numbers of these drop tests, $C_{D_{model}}$ would be less than $C_{D_{prototype}}$. This is not in keeping with the assumption made previously that $C_{D_{model}} = C_{D_{prototype}}$; however, this difference in drag would show up only as a change in simulated altitude. It is believed, then, that the effects of the low test Reynolds numbers upon the prototype simulation may be discarded as having any overshadowing effect on accomplishing the purposes of these tests, namely: to determine what first-order interference effects might be involved in making bomb releases at $M = 1.62$.

MODELS AND APPARATUS

Wind Tunnel

All tests were made in the Langley 9-inch supersonic tunnel which is a continuous, complete-return type tunnel in which the pressure may be varied and controlled from about 1/10 atmosphere to about 4 atmospheres stagnation pressure. Temperature and humidity conditions may also be varied and controlled. The Mach number is varied by interchanging nozzle blocks which form test sections about 9 inches square. A screen in the downstream end of the diffuser prevents particles from entering the compressor. For these tests an additional heavy-gauge wire basket was installed about midway down the diffuser in order to catch the bombs.

Bombs

Shown in figure 1 are the dimensions and designations of the four bombs utilized in these tests. Each of the bodies of models 1 and 2 consisted of two circular arcs of revolution joined tangentially at 40 percent of the body length. These models were simple bomb shapes designed to be used along with model 3 to ascertain the effects of bomb fineness ratio upon the release characteristics. Model 4 is a 1/70-scale model of the 5,000-pound Douglas Aircraft Co., Inc., store shape and was selected as being representative of the present-day bomb or store design. Model 3 utilizes the same body but has enlarged and modified tail fins that are also used on models 1 and 2. The fin dimensions and designations are given in figure 2. The bodies were made of lead poured onto steel inserts which supported the fins. All bodies were $3\frac{1}{2}$ inches long; therefore, changes in fineness ratio represent changes in body diameter.

Fuselage and Bomb Bays

The fuselage used in these tests consisted of a circular cylinder streamlined fore and aft with a part of the upper half removed. Interior portions of the fuselage were removable, thereby making it possible to interchange bomb-bay configurations (see fig. 3(a)). Dimensions and designations of the spoilers used with bomb bay 2 are presented in figure 3(b). The fuselage was supported by a rectangular cantilever strut (see fig. 3(c)). This strut had sharp leading and trailing edges and was supported by a circular plate which replaced one of the tunnel windows in the side wall. For bomb bays 6 and 7 the struts which suspended the bombs below the fuselage had double-wedge sections and were equipped with sway braces.

Swept Wing and Pylons

The half-span wing in this investigation was untapered, swept 30°, and had an NACA 65-009 airfoil section normal to the leading edge; the tip was cut in a streamwise direction (see fig. 4(a)). The wing was mounted through a circular plate in one of the tunnel side walls.

The wing pylons were 1/32 inch thick, untapered, with beveled leading and trailing edges sweptforward 30°, and with sway braces at the lower ends. For the majority of the tests the pylons were mounted at the 80-percent-semispan station of the wing. The chords of the short-chord and long-chord pylons were approximately 50 and 95 percent, respectively, of the bomb length with the leading edge of the pylon coincident with the leading edge of the wing in every case. The chordwise and vertical locations of the bomb centers were referenced to the 50-percent-wing-chord point at the semispan station from which the bomb was released (see fig. 4(b)). A photograph of a typical wing-pylon-bomb installation is presented in figure 4(c).

TEST METHODS AND DATA PREPARATION

While the tunnel was being brought up to speed and the tunnel pressure was being adjusted to the value specified by the similarity relation, the bomb was held in place by a spring-loaded steel wire. This wire was soldered to a small brass wire which passed through a small hole in the bomb and, in turn, was soldered to the bottom of the bomb. At the proper time of release, a moderate pull on the steel wire broke the brass wire, causing the bomb to be released without disturbing its initial attitude or position.

Each bomb release was photographed by a high-speed, motion-picture camera taking about 1,000 frames per second. The film record of each drop was then installed in a film reader, and the ordinates and abscissas of two locations on the bomb, usually the nose and the tail, were read and recorded every 1/120 second during the release. From these data, trajectory plots were prepared showing the attitude and position of the bomb at each interval of time. It is obvious that, for some cases, the bomb attitudes and positions could not be obtained whenever any part of the fuselage screened a large portion of the bomb from the line of sight of the camera.

Repeat bomb drops utilizing the same configurations of fuselage and bomb bay or wing and pylon indicated that good repeatability was obtained even for the configurations which resulted in the bomb undergoing violent variations of angle of attack. Also, two readings of the same film record indicated that the repeatability in obtaining model attitude and position was excellent.

RESULTS AND DISCUSSION

In the presentation of the trajectory diagrams (figs. 5 and 6), the fins have been removed for clarity. The fuselage and wing angles of attack and bomb angle of incidence are zero unless otherwise indicated. The effects of yaw or roll upon the pitch attitudes were believed to have been negligible.

Bomb Releases from Fuselage

The trajectory diagrams for the releases from the fuselage are presented in figure 5.

Analyses of the bomb releases from the box-type bomb bay (see fig. 5(a)) revealed that an increase in the fineness ratio of the bomb, thereby decreasing the body diameter, increased the nose-down tendency of the bomb during the early portion of the releases. Tuft studies within the bomb bay (both with and without a bomb installed) revealed that a strong counterclockwise circulation of flow was present, as viewed in figure 5(a), which caused the nose-down tendency of the bombs. As the bomb diameter increased, this circulation apparently became restricted, thereby resulting in a smaller nose-down pitching-moment increment for the bomb (compare releases of bombs 1, 2, and 3, fig. 5(a)). Likewise, a decrease in fin size and, consequently, a decrease in the interference lift of the fins resulted in improved release characteristics at simulated altitudes of 40,000 and 30,000 feet (compare bombs 3 and 4, fig. 5(a)). In general, an improvement in release characteristics occurred as the simulated altitude was increased; however, this is to be expected to some degree since the interference forces on the bomb become smaller as the dynamic pressure is reduced. The aforementioned flow circulation appeared similar to that discussed in reference 1.

Effects of angle of attack and bomb incidence were investigated using bomb 4 and the box-type bomb bay (see fig. 5(b)). An increase in the flow circulation as a result of a positive angle of attack of 4° caused severe nose-down tendencies even at a simulated altitude of 40,000 feet. At $\alpha = -4^\circ$ the opposite was true, and large improvements in the release characteristics were evident at all simulated altitudes. Little, if any, change in the release characteristics was evidenced as a result of releasing bomb 4 at a positive angle of incidence of 4° (compare figs. 5(a) and 5(b)).

In a further effort to improve the release characteristics of bomb 4 from the box-type bomb bay, both solid and perforated spoilers were placed at the front of the bomb bay; however, little, if any, change in the release characteristics was noted as a result of the use of these spoilers (compare figs. 5(a) and 5(c)).

The installation of three baffles within the bomb bay, normal to the fuselage axis, altered the flow sufficiently to show large improvements in the releases of bombs 2, 3, and 4 at a simulated altitude of 20,000 feet (compare figs. 5(a) and 5(d)). Even at 10,000 feet the releases were not objectionable.

Removal of the forward and rearward inner portions of the box-type bomb bay altered that configuration into a complete channel (bomb bay 4). Because of the alteration of the geometry of the configuration, the flow circulation no longer existed. With a bomb installed within the channel, the flow was partially blocked; a pressure increase apparently took place over the forward portion of the bombs, in particular, the region between the nose of the bomb and the upper surface of the channel. This pressure increase, in conjunction with the ensuing downward flow deflection, caused a slight nose-down tendency during the initial portion of the drop (see fig. 5(e)). There was little variation in the release characteristics due to change in bomb configuration or simulated altitude.

The bomb releases from the semiexternal bomb bay showed tendencies for the bombs to nose up immediately after release (see fig. 5(f)). This nose-up tendency was worse for the low-fineness-ratio bombs which had small static margins; for instance, when released at a simulated altitude of 20,000 feet, bomb 1 collided with the underside of the fuselage. Also, little effect could be noted as a result of enlarging the fins. It is believed that the primary factor which contributed to this nose-up tendency was the downward deflection of the flow from the fuselage cavity onto the afterportions of the bombs and their fins as the bombs were leaving the fuselage. Also, it is possible that the pressure distribution over the exposed portion of the bomb could have been altered by the presence of the fuselage so as to produce nose-up pitching moments.

An attempt to reduce the aforementioned nose-up release tendencies by suspending the bombs on struts 1/5 bomb length below the fuselage was not successful (see fig. 5(g)), and the releases were similar to those obtained from the semiexternal bomb bay. Here again, the effects of increasing bomb fineness ratio or simulated altitude were to improve the release characteristics of the bombs. Again it appears that the fuselage cavity causes a downward deflection of the flow onto the afterportions of the bombs and results in nose-up tendencies.

Filling in the cavity so that the bombs were suspended beneath a smooth fuselage resulted in the removal of the majority of the nose-up tendencies for bombs 1, 2, and 3 (see fig. 5(h)). Variations of bomb configuration or simulated altitudes resulted in minor changes in the bomb release characteristics.

Bomb Releases From Wing Pylons

The trajectory diagrams for the releases from the wing pylons are presented in figure 6. In figure 6(a) it is apparent that for the bombs located at $x/l = 0.25$ and $z/l = 0.05$ serious nose-down tendencies were present immediately after release. This occurred primarily as a result of the fact that the flow beneath the wing leading edge impinged on the forward portions of the bombs. Because of this change in bomb attitude during the early portion of the drop, the upper fins struck the lower wing surface. Although the model motions do not simulate prototype motions (except in near-level releases), it is believed that such changes in bomb attitude are indicative of the changes that would be expected of the prototype. Increasing the bomb fineness ratio improved the releases slightly; the effects due to changes in simulated altitude were negligible.

Moving the bomb forward so that its center of gravity was located at $x/l = 0.50$ removed a portion of the nose-down tendency, especially for bomb 3. However, for bomb 2 a noticeable nose-up tendency took place shortly after the bomb nosed down. This will be discussed later in this section.

In a further effort to improve these releases, the gap between the wing and bombs was enlarged from $z/l = 0.05$ to $z/l = 0.15$ (see fig. 6(b)). With the bomb center of gravity located at $x/l = 0.25$, nose-down tendencies were present similar to those for $z/l = 0.05$. Moving the bombs forward to $x/l = 0.50$ removed the nose-down tendencies entirely. For bombs 1 and 2, the previously mentioned nose-up tendency took place after the bombs had maintained a near-level attitude for a short interval of time and was very apparent, more so than for bomb 3. The reason for this nose-up tendency is believed to be associated with the distribution of the vertical component of flow in the z-direction (probably the downward inclination of flow as it passes through the shock caused by the wing leading edge) and its effect upon the pressure distribution of the bomb bodies. This assumption is based upon the fact that, even though the bombs were mounted at different vertical positions, the pitch-up of the bombs appeared to be initiated at approximately the same vertical distance below the wing. Thus, the nose-up tendency would occur at a later time interval after the release for the bombs released from $z/l = 0.05$ than for the bombs released from $z/l = 0.15$ (as substantiated by comparison of figures 6(a) and 6(b)). In summary, releasing the bombs from a more forward and a more downward location improved the release characteristics, the best releases being made by the bomb with the more rearward center-of-pressure location (bomb 3). It is of interest to note that results presented in reference 5 indicated that lower incremental drags were obtained as a result of installing a 500-pound Douglas Aircraft Co., Inc., store shape (without fins) in more forward positions while maintaining a constant gap between wing and bomb.

An effort was made to alleviate the fin gouging which occurred during the drops from $x/l = 0.25$ and $z/l = 0.05$. This constituted extending the trailing edge of the pylon rearward to the rear of the bomb so that during release any nose-down rotation would take place about the rear of the bomb; this pylon has been designated the long-chord pylon. As indicated in figure 6(c) this scheme was successful in preventing the aforementioned fin gouging.

Two additional releases, results of which are not presented herein, were made using bomb 3 at simulated altitudes of 20,000 and 30,000 feet from a position $x/l = 0.25$ and $z/l = 0.15$; the releases were made from the 40-percent-semispan station. Results of these two releases, as compared with the results of similar releases made from the 80-percent-semispan station (fig. 6(b)), indicated that the effects of moving the release station inboard were negligible.

CONCLUSIONS

As a result of these bomb-release tests at a Mach number of 1.62 and at Reynolds numbers from about 0.1×10^6 to about 0.4×10^6 the following conclusions are indicated:

1. The effects of increasing altitude were, in most cases, beneficial to the release characteristics of a bomb.

2. In making releases from an internal box-type bomb bay of the type common to subsonic bombers (bomb bay 1), it appears beneficial to reduce the flow circulation within the bomb bay by reducing the clearance around the bomb or by using transverse baffles within the bomb bay.

3. Of the seven bomb-bay configurations utilized, the release characteristics of bomb drops from the complete channel, the external bomb bay, and the box-type bomb bay with transverse baffles were superior throughout a wide range of altitudes and bomb configurations to the releases from the other bomb bays.

4. The results of releases from semiexternal and external mounts below the fuselage and from pylons beneath the wing indicated that the best release characteristics were obtained when the bomb with the most rearward center-of-pressure location was used.

5. As in the case of bomb releases at high subsonic speeds, the bomb position beneath the swept wing is of primary importance to the release characteristics of the bomb. For the present tests, moving the bomb forward and downward from the wing improved the release characteristics. Results of force tests of similar configurations indicated that this is in the direction to reduce the incremental drag due to the installation of the bomb.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 11, 1953.

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2. Muse, Thomas C.: Wind Tunnel Drop Tests of Several Typical Bombs From a Swept-Wing Hypothetical Bomber. Rep. No. ES 15465, Douglas Aircraft Co., Inc., May 15, 1950.

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4. Rainey, Robert W.: Effect of Variations in Reynolds Number on the Aerodynamic Characteristics of Three Bomb or Store Shapes at a Mach Number of 1.62 With and Without Fins. NACA RM L53D27, 1953.

5. Jacobsen, Carl R.: Effects of the Spanwise, Chordwise, and Vertical Location of an External Store on the Aerodynamic Characteristics of a 45° Sweptback Tapered Wing of Aspect Ratio 4 at Mach Numbers of 1.41, 1.62, and 1.96. NACA RM L52J27, 1953.

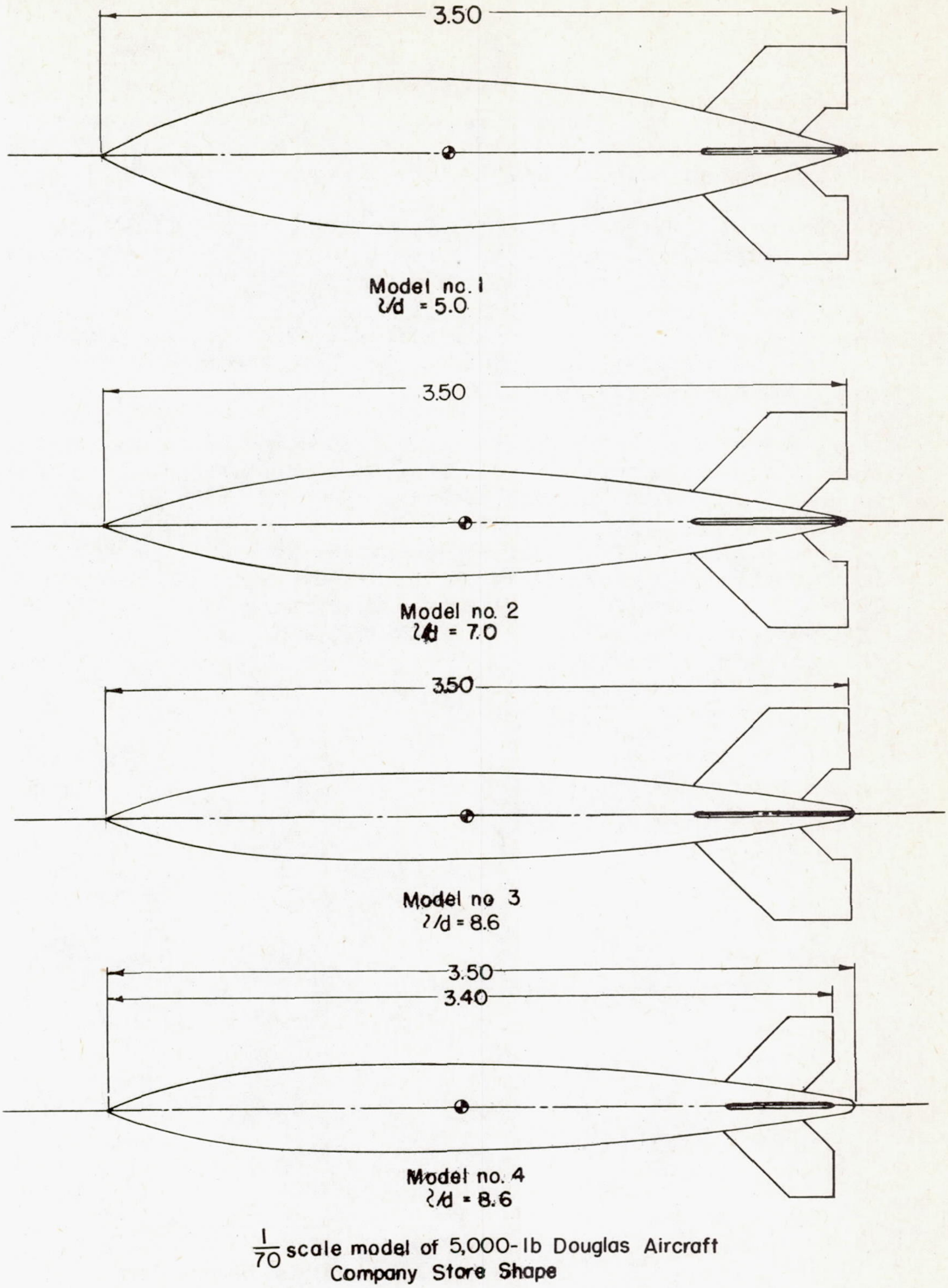
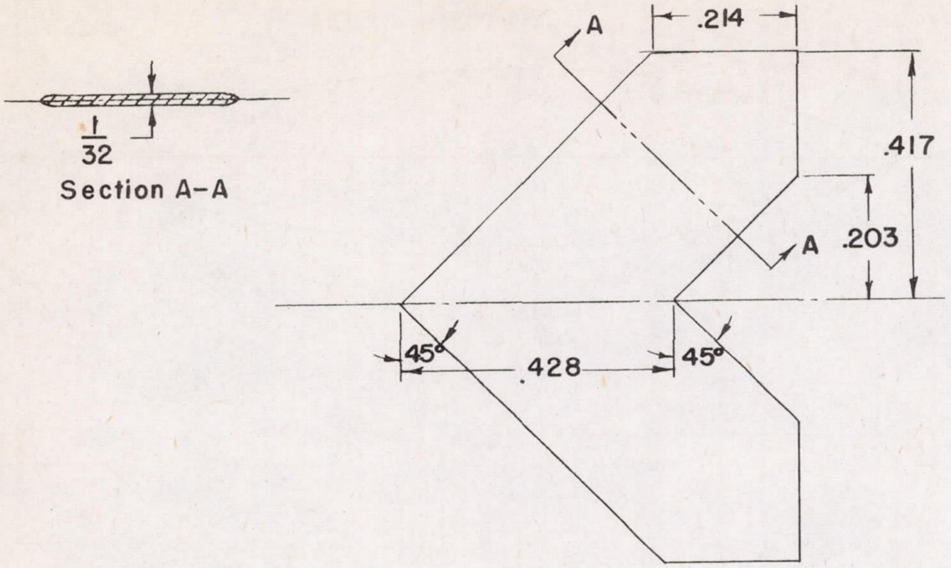
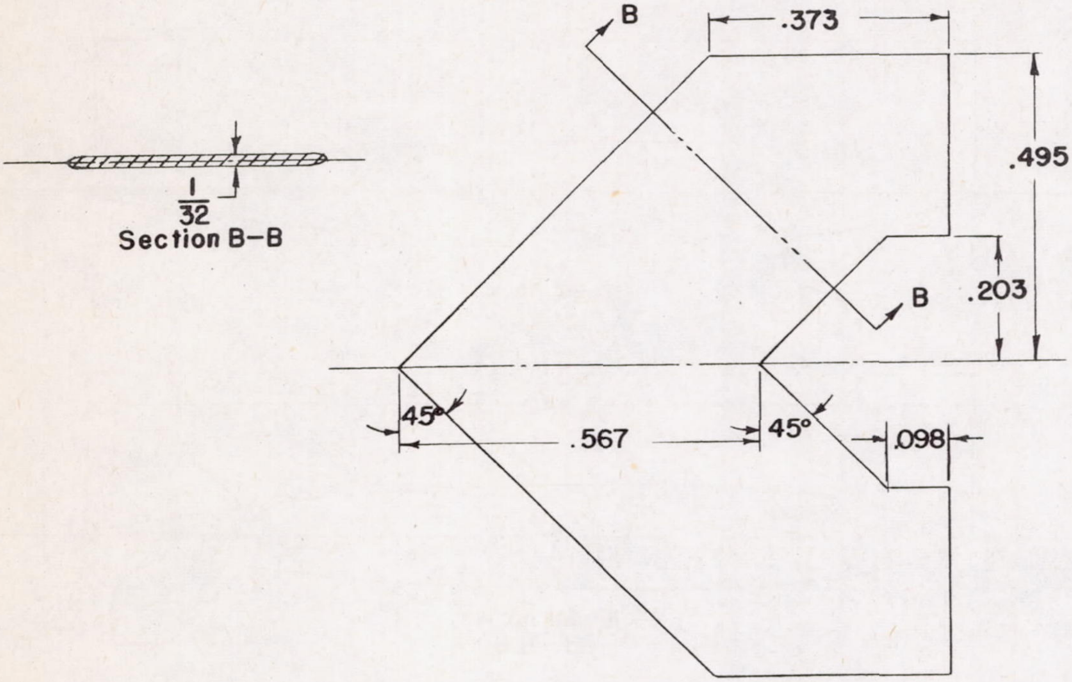


Figure 1.- Model dimensions and designations. All centers of gravity at about 47 percent of the body length.

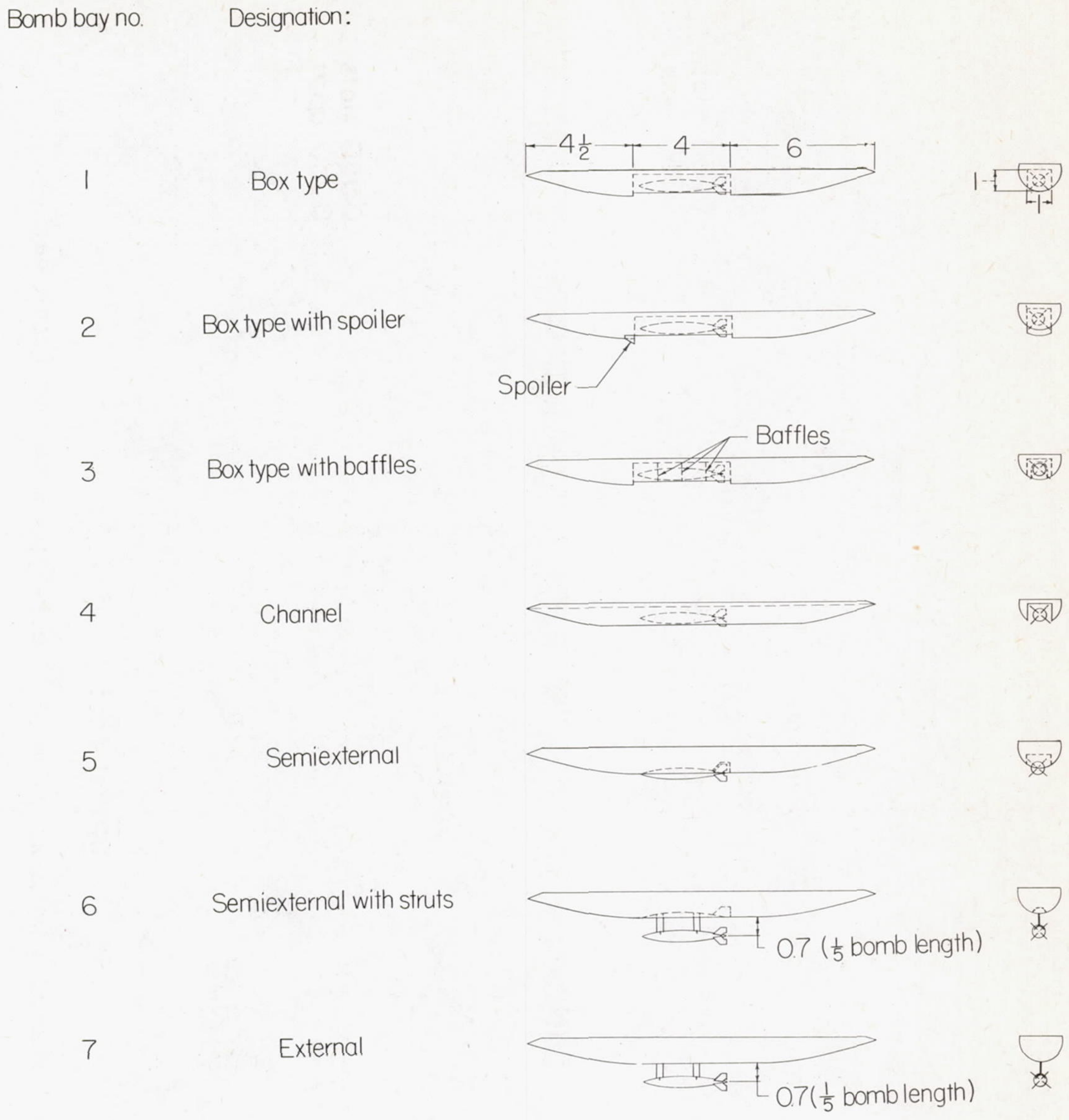


Original fin from D.A.C. Store shape
Model 4



Enlarged and modified fin plan form
Models 1, 2, and 3

Figure 2.- Fin dimensions and designations.

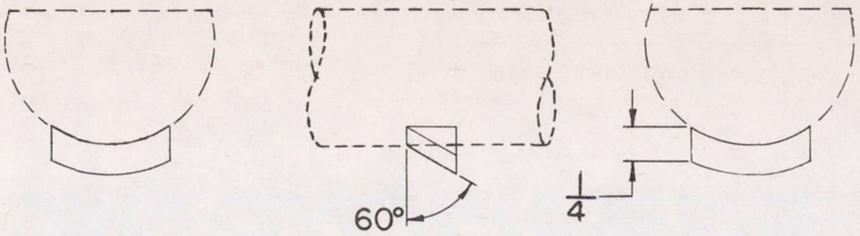


ORDINATES OF FUSELAGE NOSE AND TAIL:

DISTANCE FROM APEX	0	0.600	1.200	1.800	2.600	3.000	3.400	3.800	4.200	4.500
BODY RADIUS	0	.204	.395	.550	.710	.770	.815	.850	.870	.875

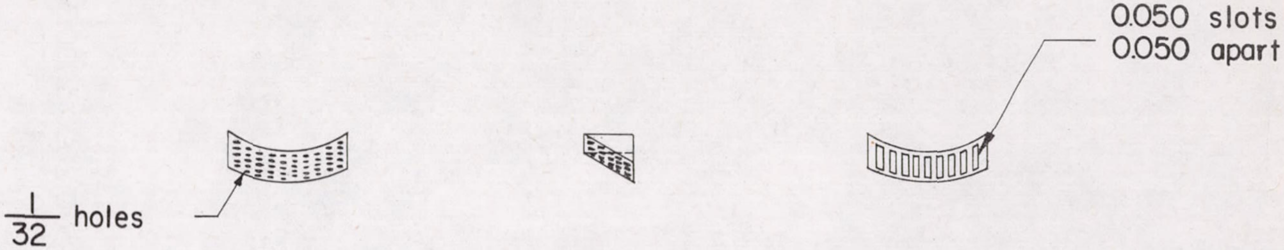
(a) Bomb-bay configurations and designations (all dimensions are in inches).

Figure 3.- Fuselage—bomb-bay installation.

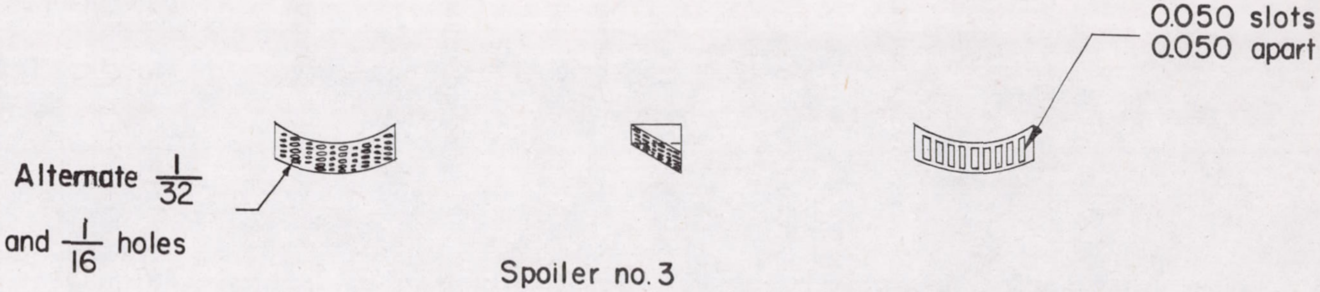


Spoiler no. 1

Solid



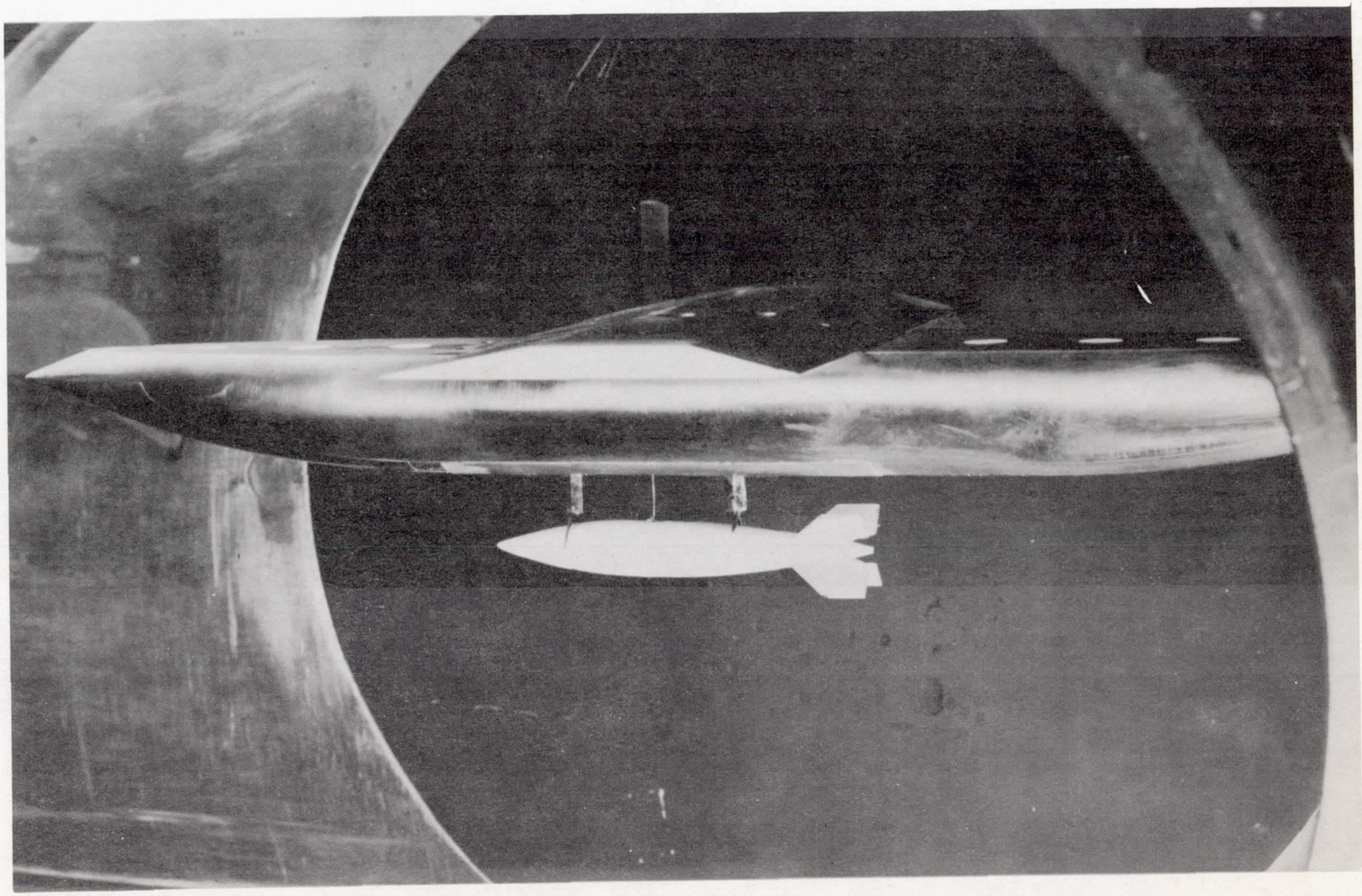
Spoiler no. 2



Spoiler no. 3

(b) Spoiler configurations used with box-type bomb bay (bomb bay 2).

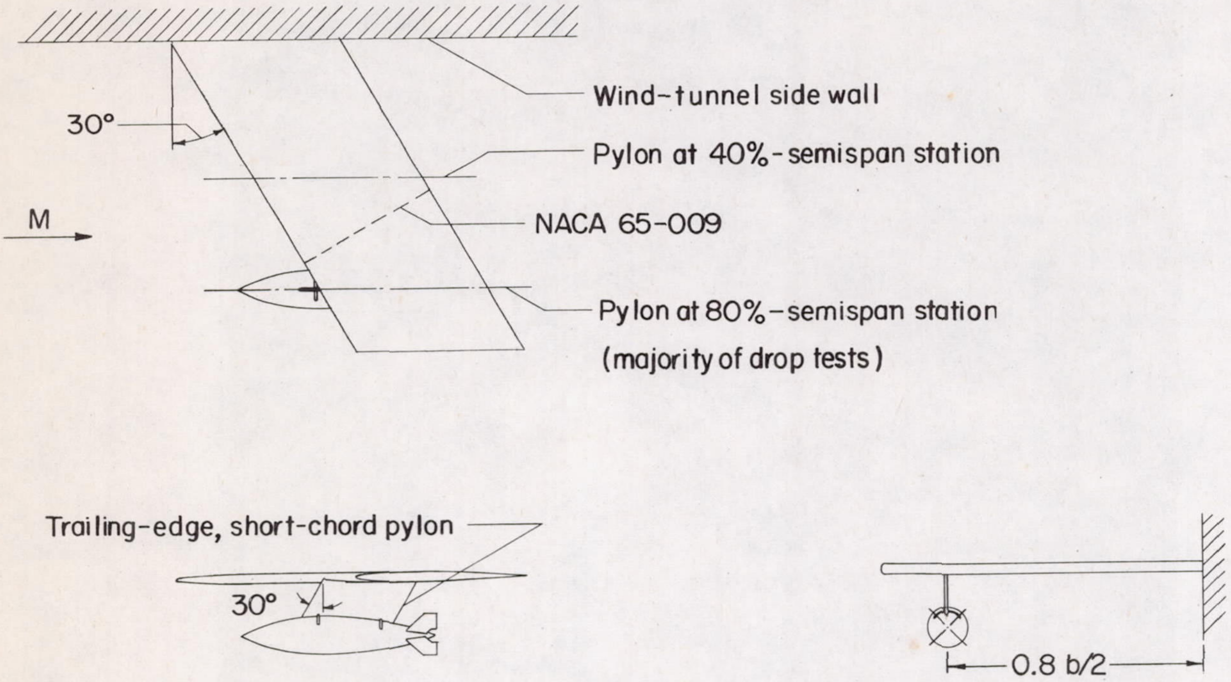
Figure 3.- Continued.



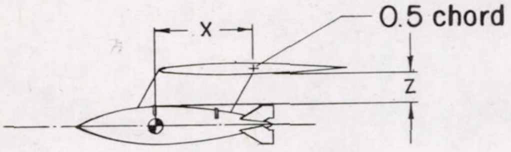
L-81402

(c) Typical model installation in wind tunnel for bomb-bay release.

Figure 3.- Concluded.

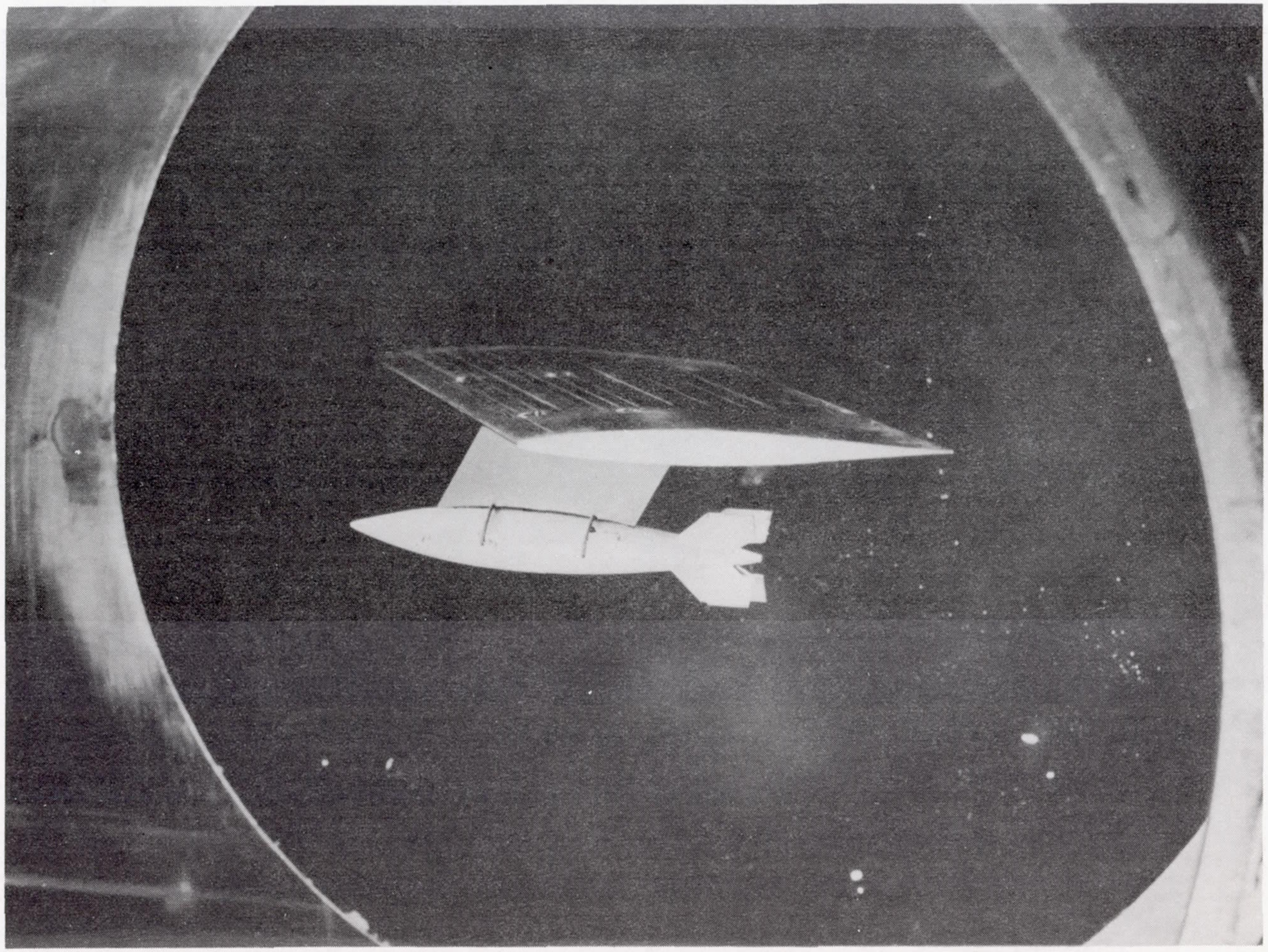


(a) Typical bomb-wing-pylon installation.



(b) Definitions of x and z.

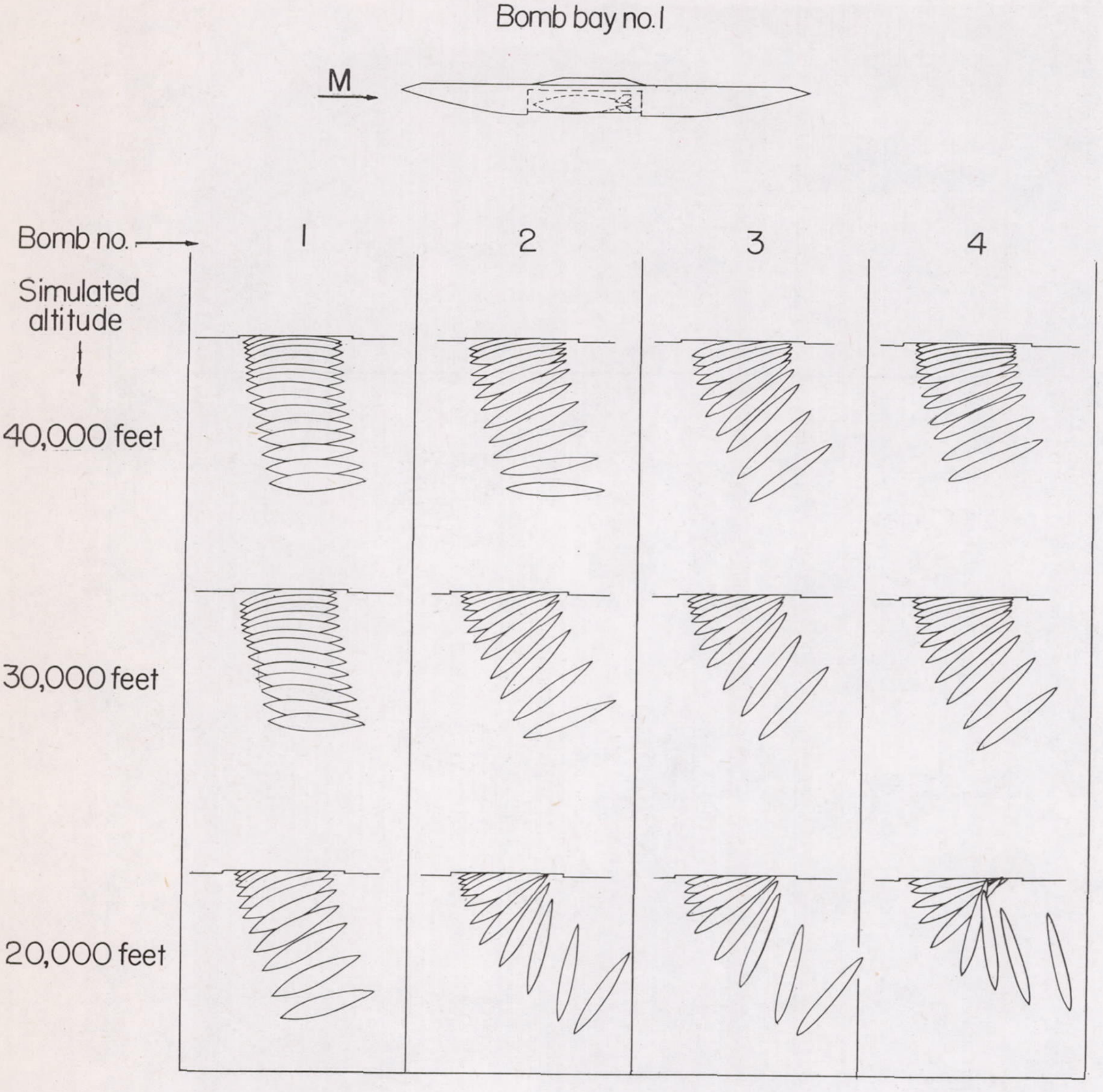
Figure 4.- Bomb—wing-pylon installation.



L-81401

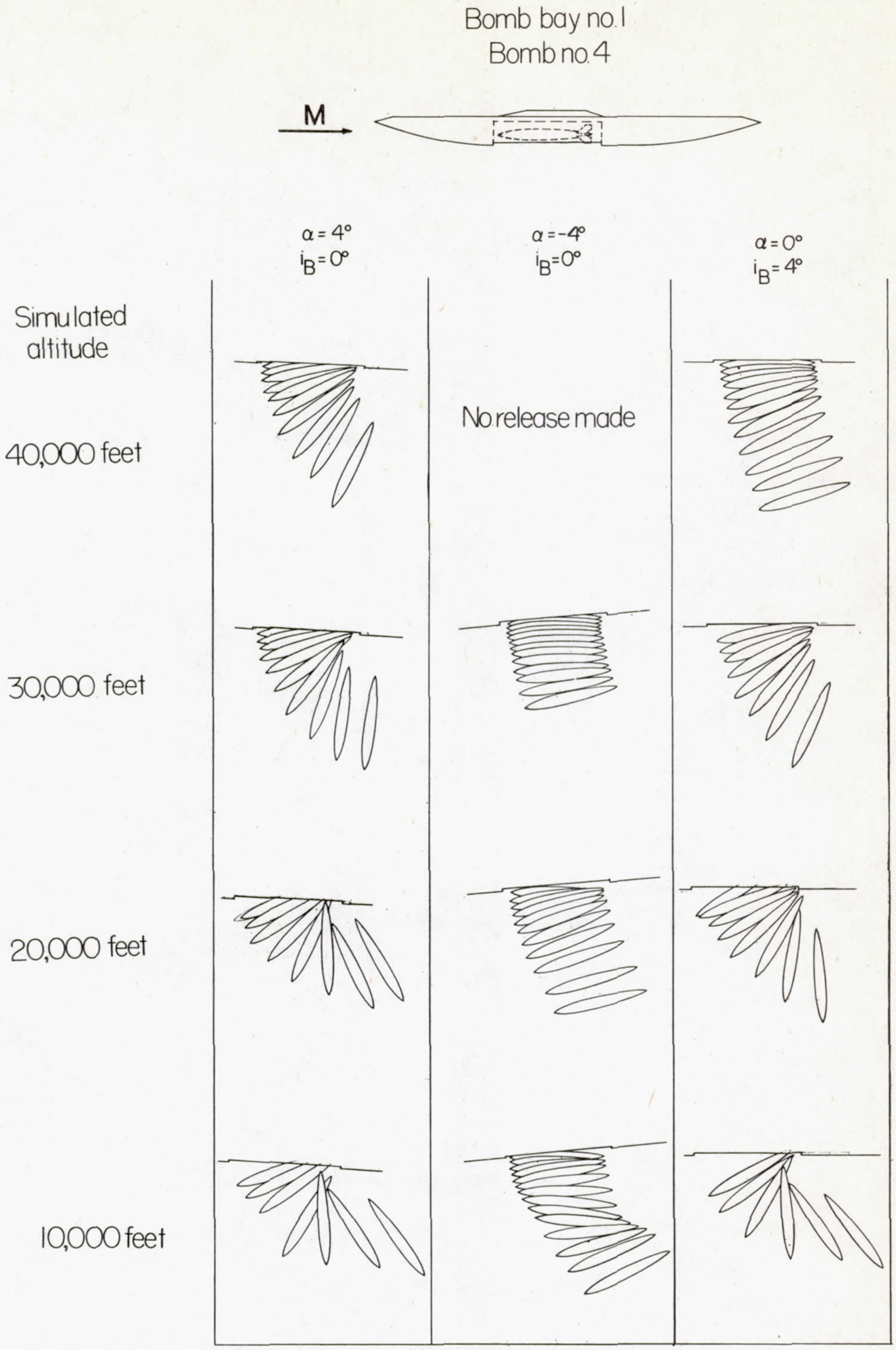
(c) Typical model installation in wind tunnel for wing-pylon release.

Figure 4.- Concluded.



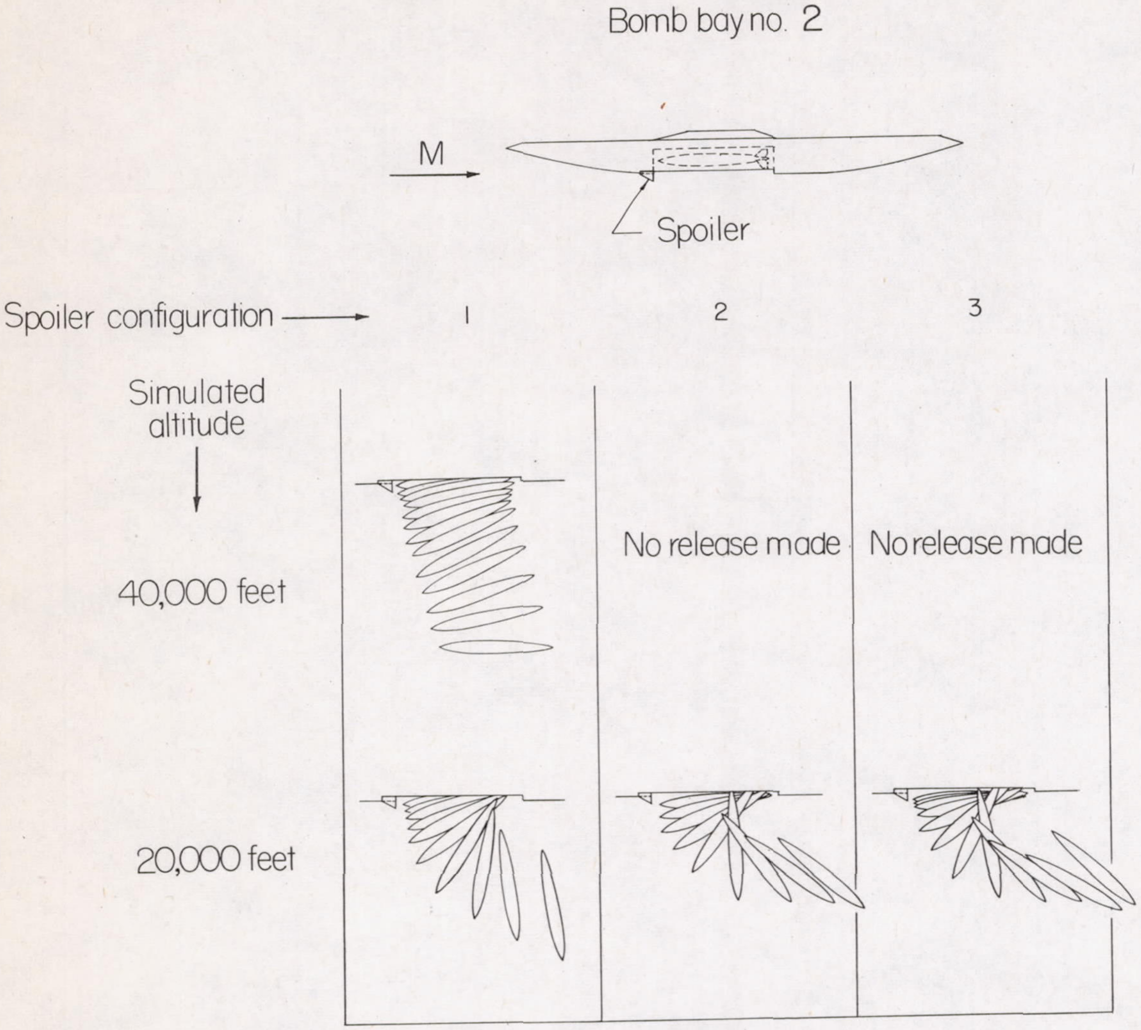
(a) Bomb bay 1.

Figure 5.- Bomb releases from bomb bays (fins removed for clarity).



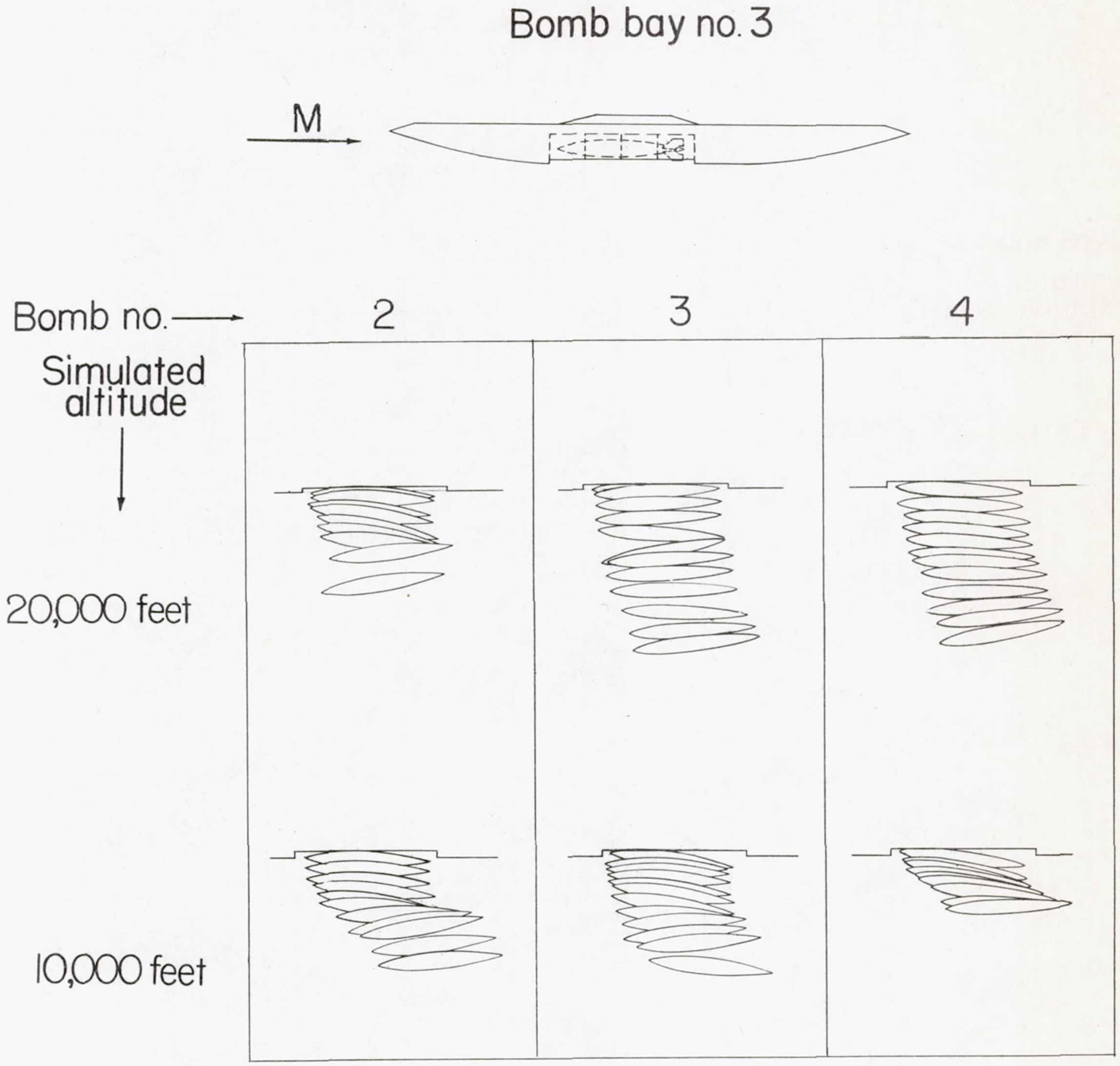
(b) Bomb bay 1 with various values of α and i_B using bomb 4.

Figure 5.- Continued.



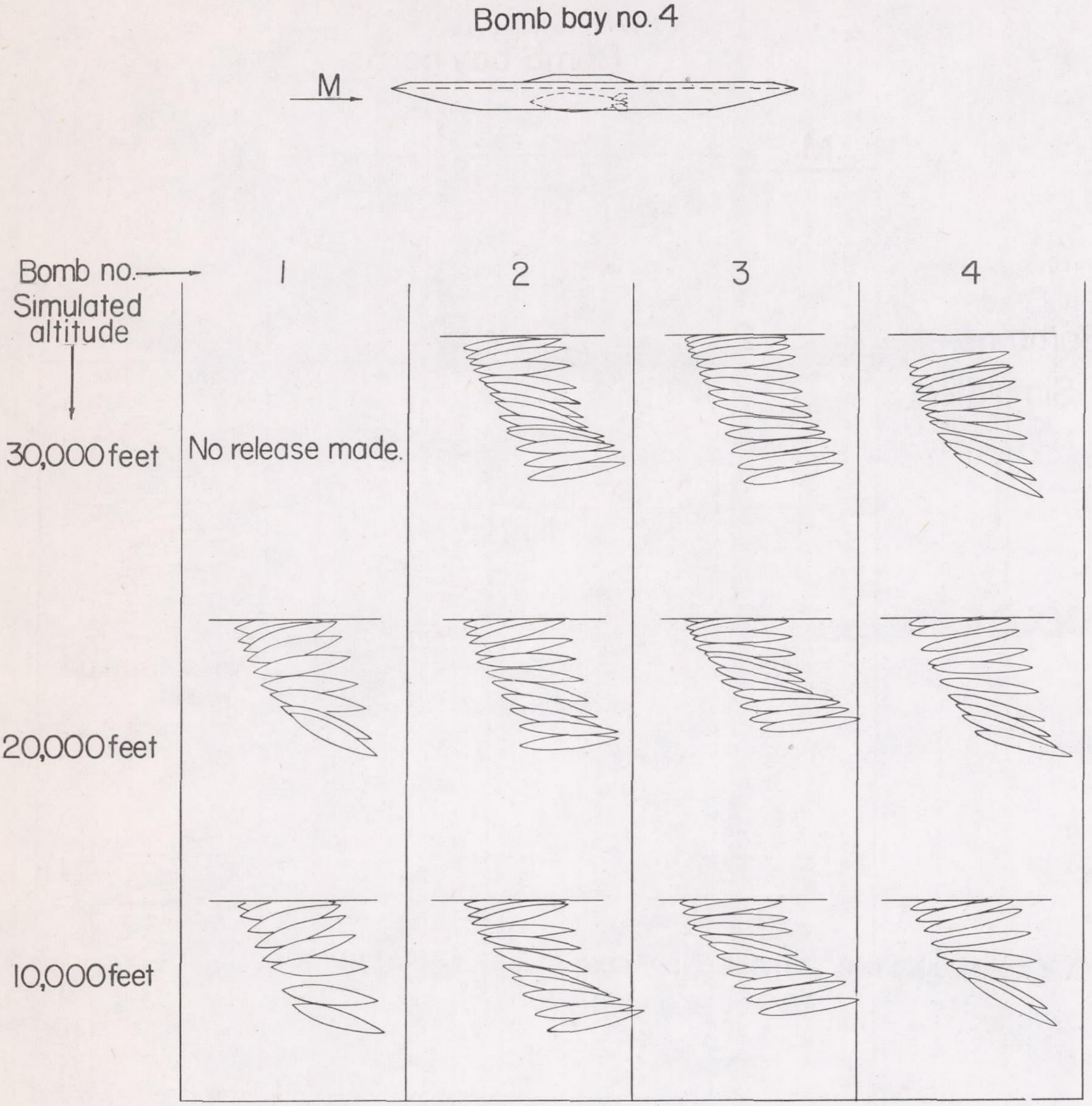
(c) Bomb bay 2 using bomb 4.

Figure 5.- Continued.



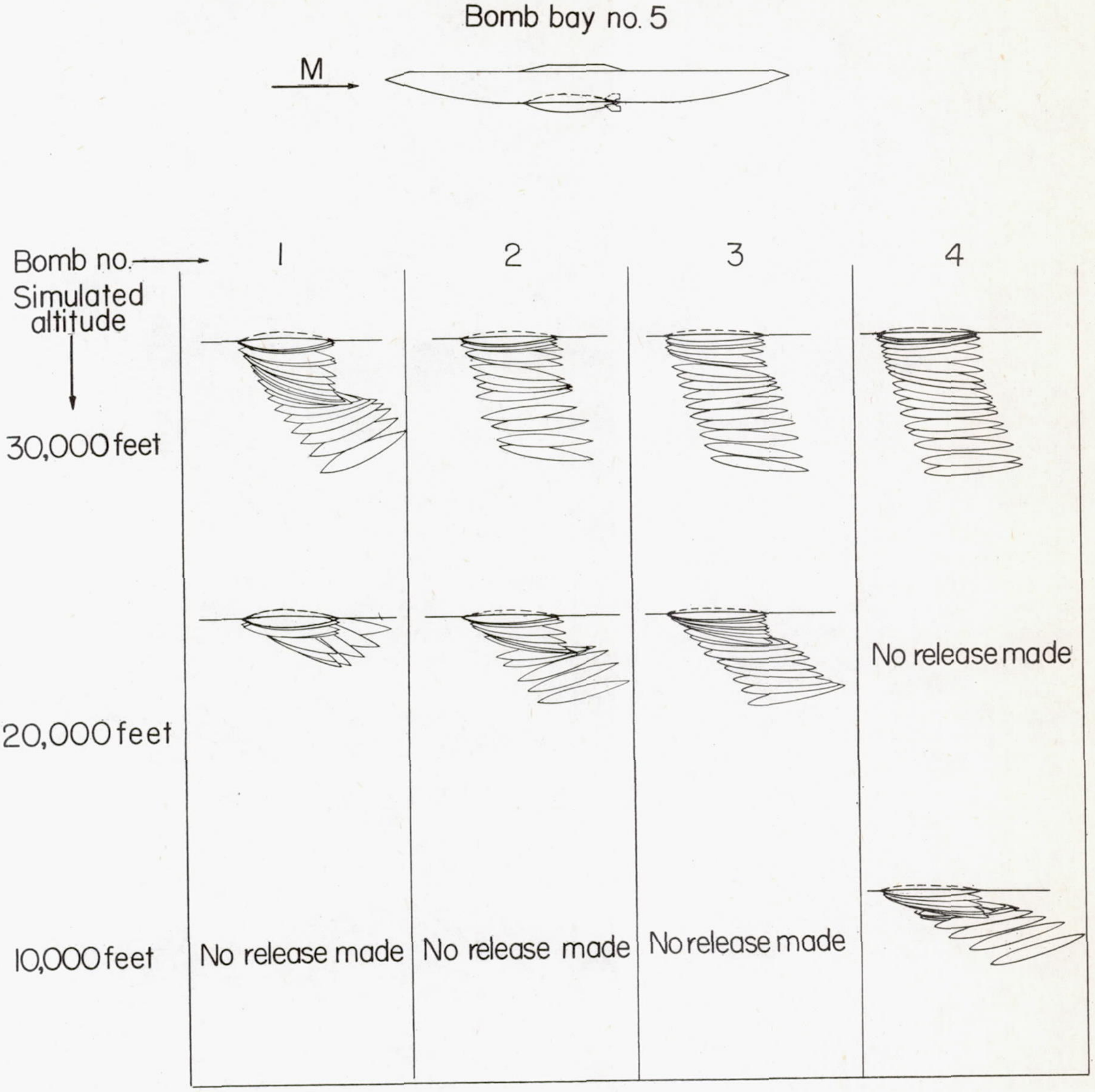
(d) Bomb bay 3.

Figure 5.- Continued.



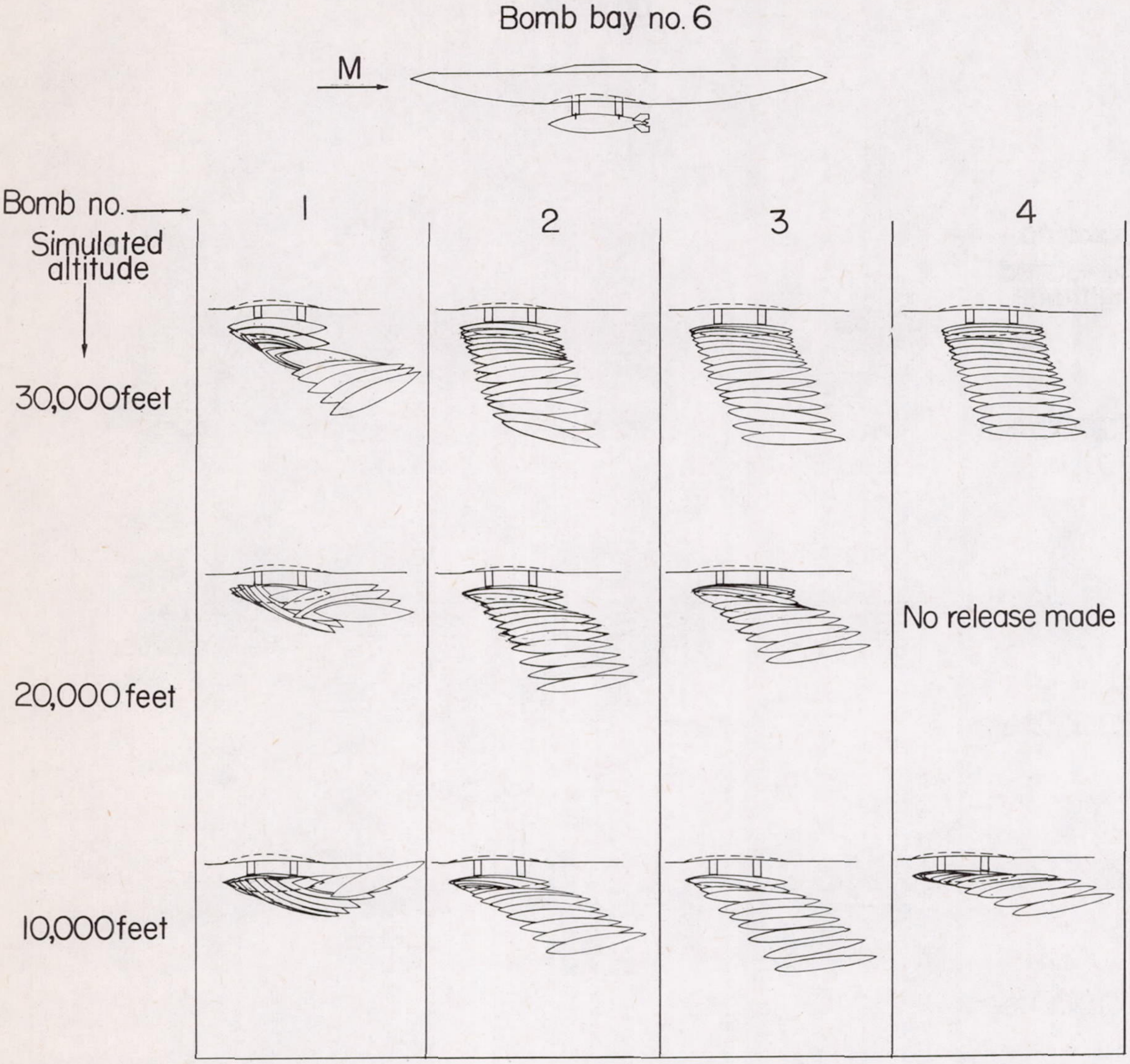
(e) Bomb bay 4.

Figure 5.- Continued.



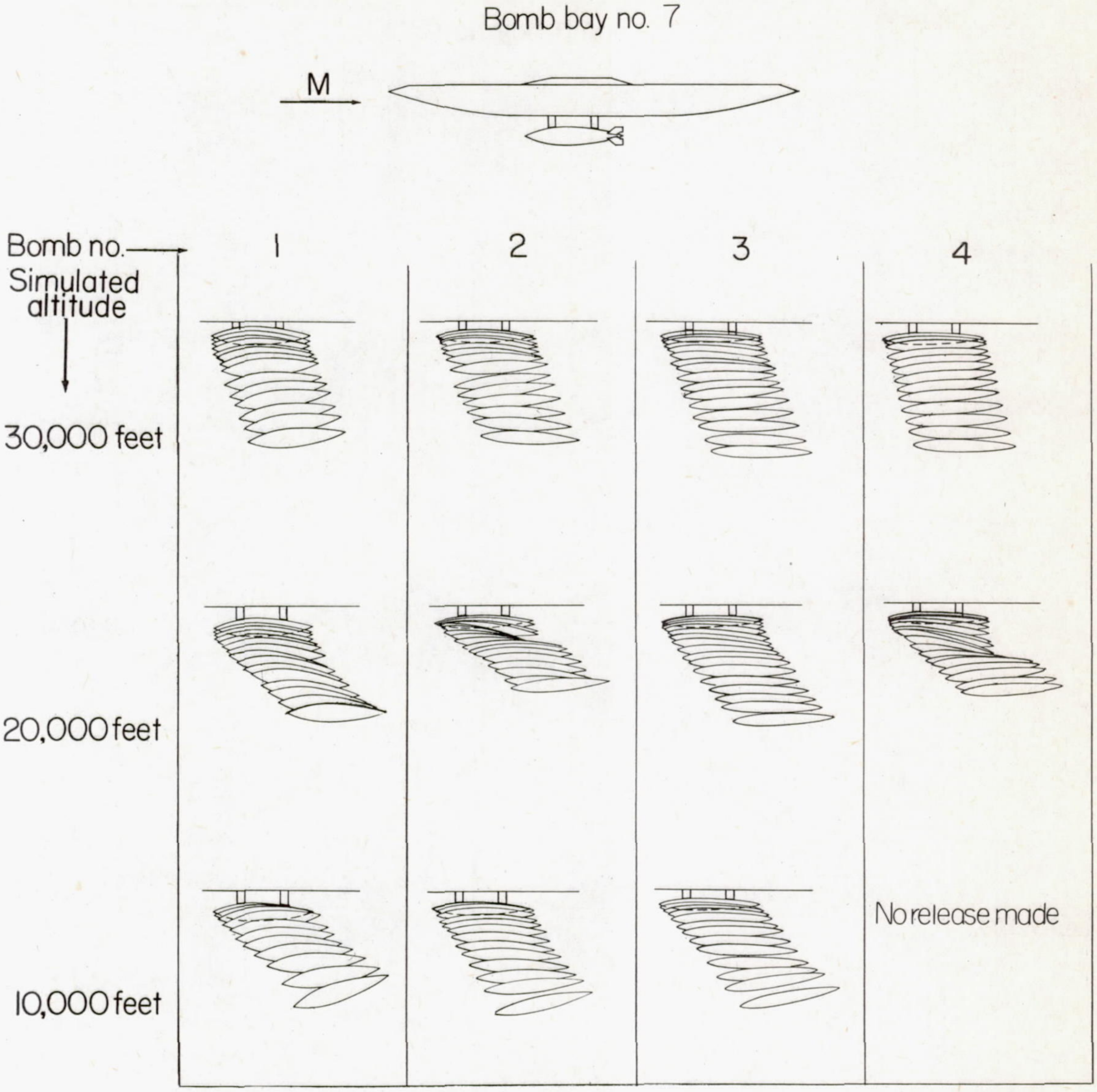
(f) Bomb bay 5.

Figure 5.- Continued.



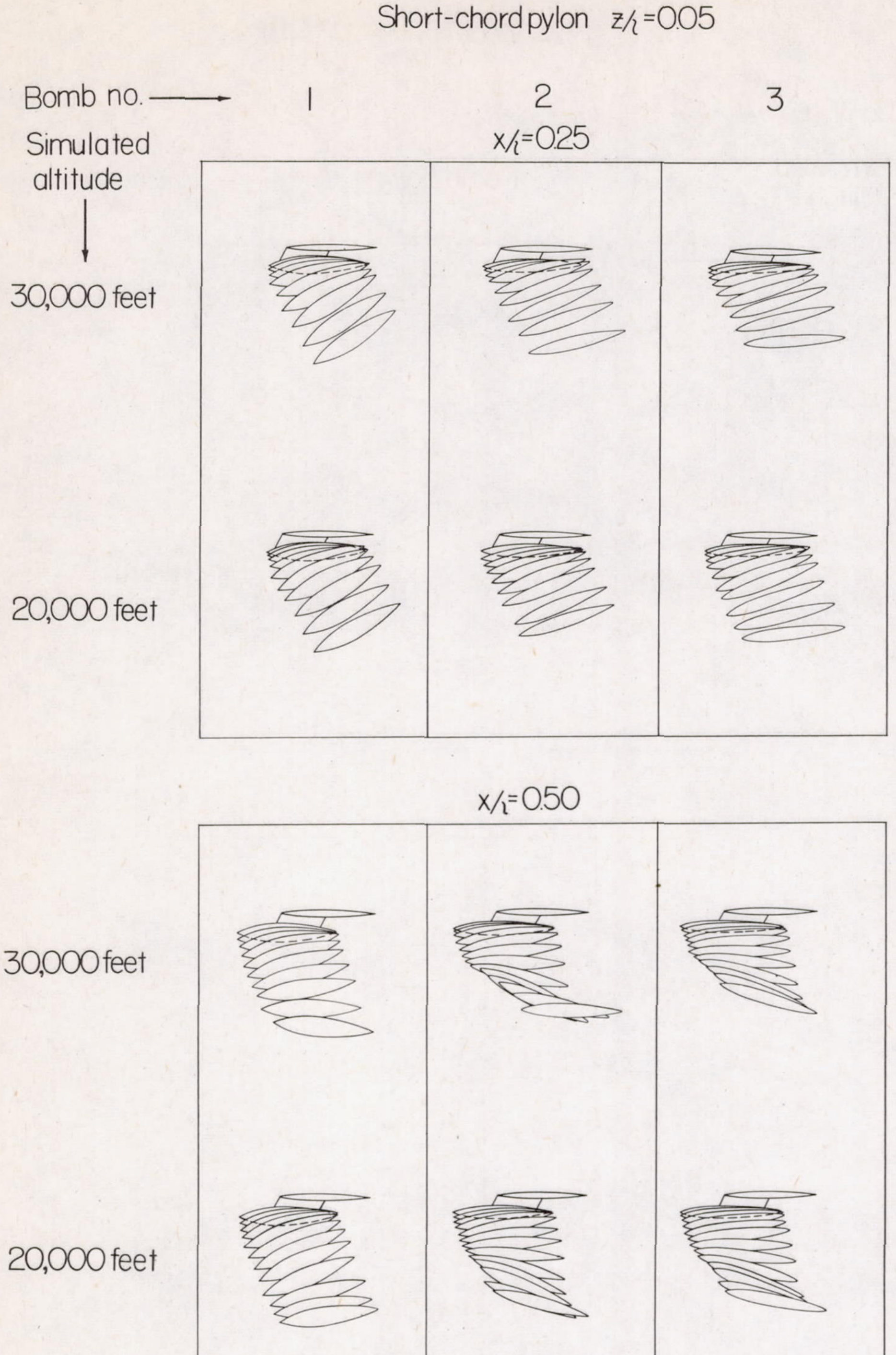
(g) Bomb bay 6.

Figure 5.- Continued.



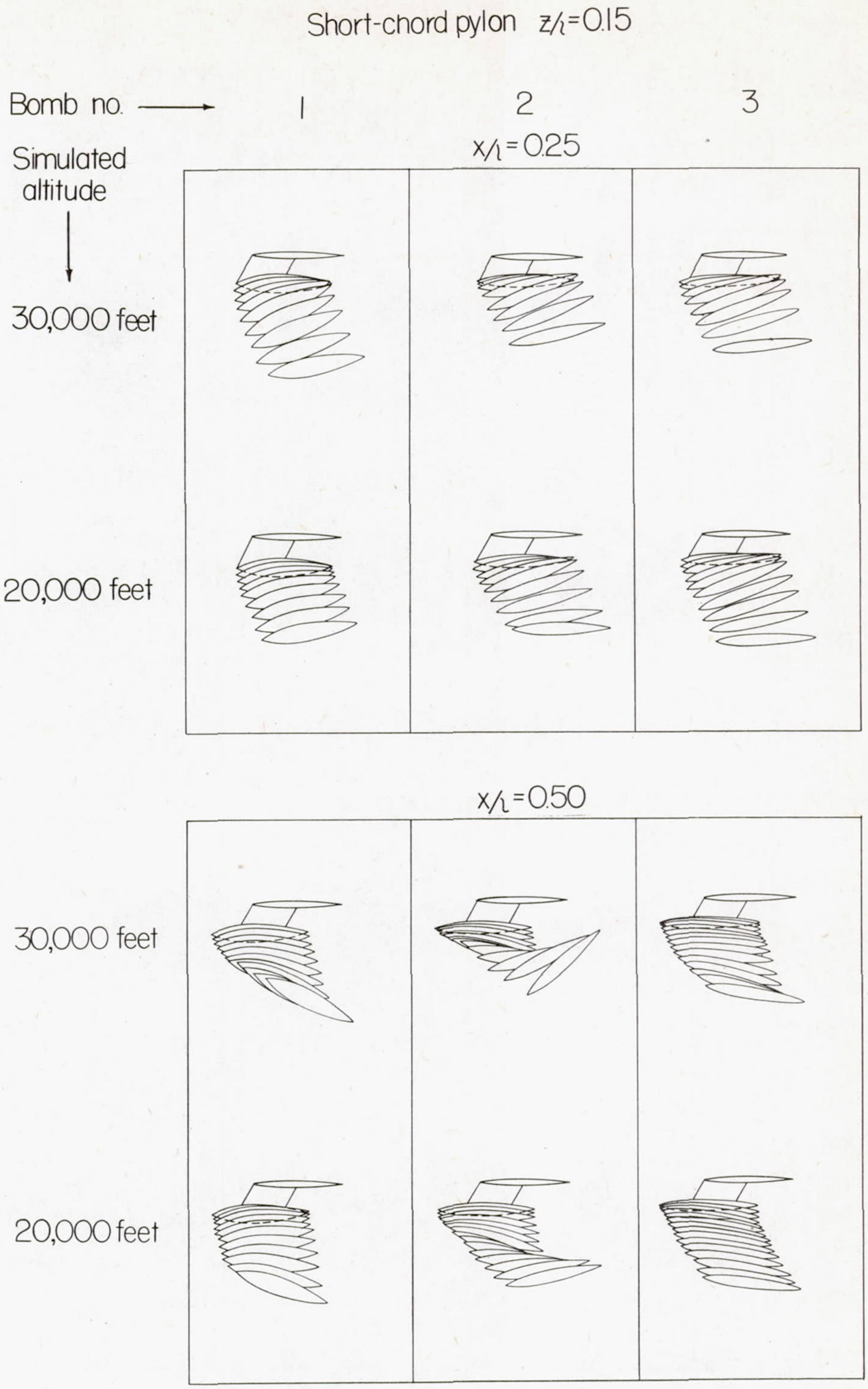
(h) Bomb bay 7.

Figure 5.- Concluded.



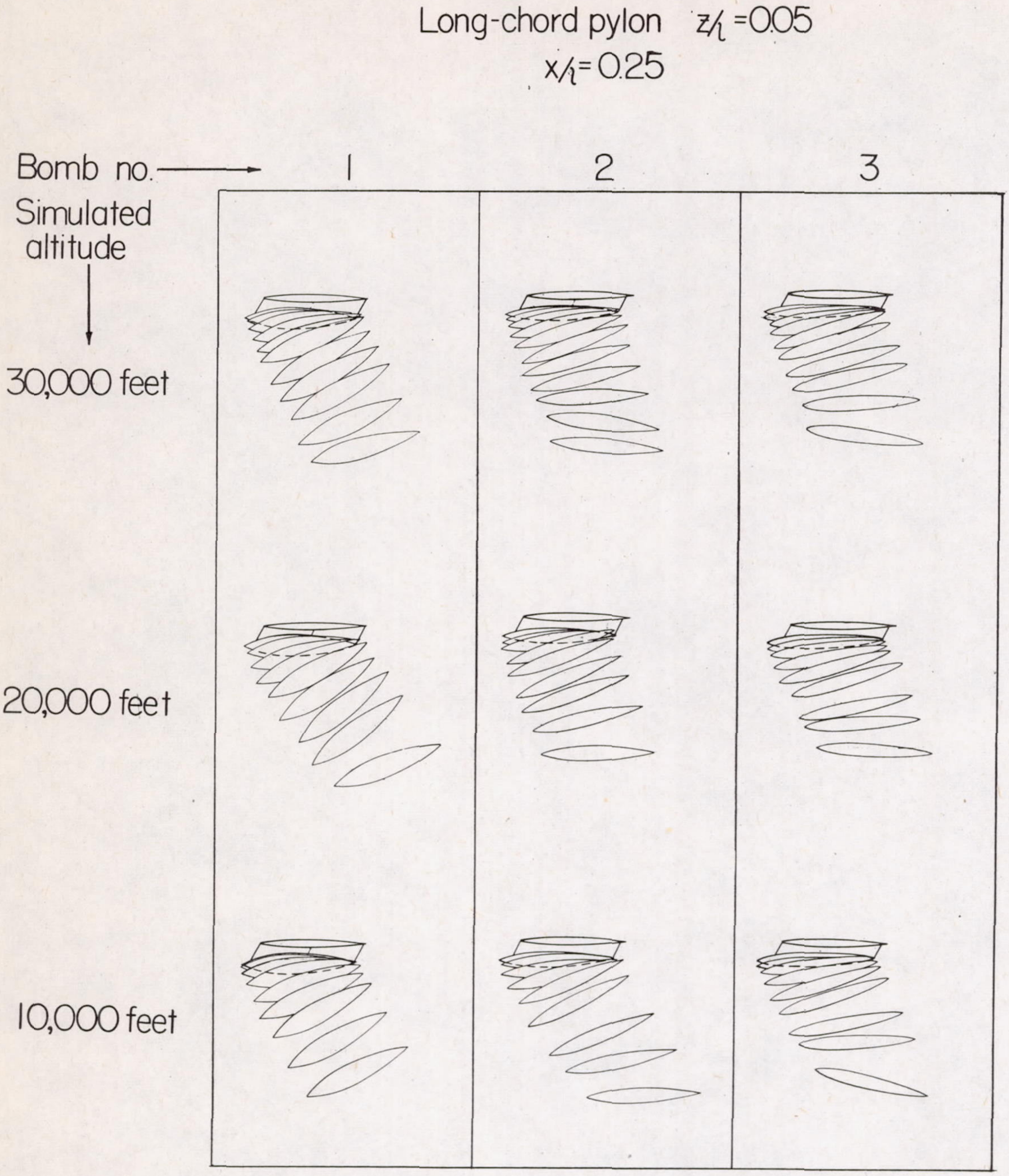
(a) Short-chord pylon; $z/l = 0.05$; $x/l = 0.25$ and 0.50.

Figure 6.- Bomb releases from wing pylons at 0.80b/2 (fins removed for clarity).



(b) Short-chord pylon; $z/l = 0.15$; $x/l = 0.25$ and 0.50.

Figure 6.- Continued.



(c) Long-chord pylon; $z/l = 0.05$; $x/l = 0.25$.

Figure 6.- Concluded.