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RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

DITCHING TESTS OF TWO MODELS OF THE ARMY B-36 AIRPLANE

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

The ditching characteristics of the Army B-36 airplane were determined by testing $\frac{1}{20}$- and $\frac{1}{30}$-scale dynamic models in calm water in Langley tank no. 2 and at the outdoor catapult. The scope of the tests consisted of ditching the models at various conditions of simulated damage, landing attitudes, and speeds, with various flap settings using several degrees of restraint of the flap hinges. The ditching behavior was evaluated from recordings of deceleration, length of run, and motions of the models.

The results showed that the airplane should be ditched at an attitude of about 9° with flaps full down. The probable ditching behavior will be a smooth run with a maximum longitudinal deceleration of 3g to 4g and a landing run of 4 to 5 fuselage lengths.

Structural failure of the underside of the fuselage will not seriously affect the behavior of the airplane.

INTRODUCTION

The object of the tests was to determine the probable ditching behavior of the Army B-36 airplane and the best way to ditch it. A three-view drawing of the airplane is shown as figure 1.

The tests, which were made in calm water in Langley tank no. 2 and at the outdoor catapult, were requested by the Air Materiel Command, U. S. Air Force. Data on the full-scale airplane were obtained from the Consolidated Vultee Aircraft Corporation.

APPARATUS AND PROCEDURE

Description of Models

Ditching tests were made with two models of the B-36 airplane - one of $\frac{1}{30}$ scale the other of $\frac{1}{20}$ scale. The $\frac{1}{30}$-scale model, which was built to a standard and convenient size, was to have been used for the majority of the tests. The $\frac{1}{20}$-scale model was built to a scale which, it was believed, would facilitate model construction and allow more disposable weight for instrumentation. During the course of the tests, the $\frac{1}{30}$-scale model was accidentally destroyed by fire, so the program was completed with the larger model.

The wing spans of the small and large model were 7.67 feet and 11.50 feet, respectively. Figures 2 to 6 are photographs of the models. Both models were dynamically similar to the airplane; that is, the linear dimensions, weight, and moments of inertia were to scale. The type of construction was similar to that described in reference 1.

The vertical tail on both models was made smaller than scale size to meet moment-of-inertia requirements. The altered tails were adequate aerodynamically for the short glides of the tests, and, since they never entered the water, they did not affect the hydrodynamic behavior. Both models had outboard midchord slots. (See figs. 3 and 4.) These slots were open for full-down and half-down flaps and were closed for full-up flaps.

Aerodynamic tests of the $\frac{1}{30}$-scale model indicated that the wing was stalling at high attitudes; therefore, full-span slats were attached along the leading edge of the wing. These slats were not a part of the full-scale airplane as were the outboard midchord slots. The $\frac{1}{20}$-scale model had adequate lift characteristics for the attitudes tested so the addition of slats was not necessary.

Friction hinges were used to give the model flaps their requisite scale strength. These friction hinges permitted the flaps to pivot up when water loads became greater than a given limit, thus simulating failure of the flaps.

Because of moment-of-inertia requirements, it was not feasible to install an accelerometer in the $\frac{1}{30}$-scale model.

Test Methods and Equipment

Tank tests.- The $\frac{1}{30}$-scale model was tested in smooth water in Langley tank no. 2. The apparatus and test procedure were similar to those described in reference 1.

Catapult tests.- The $\frac{1}{20}$-scale model was too large to test in the tank so it was tested only at the outdoor catapult. The apparatus and test procedure were similar to those described in reference 1. A brief description of the time-history accelerometer used in this model is given in reference 2.

Test Conditions

(All values refer to the full-scale airplane)

Gross wieght.- The model weight corresponded to a gross weight of 255,000 pounds.

Location of center of gravity.- The center of gravity was located at 29.0 percent of the mean aerodynamic chord and 3.61 feet below the deck line.

Landing gear.- No landing gear was provided on the models, and all tests simulated ditchings with the landing gear retracted.

Attitude.- The landing attitudes investigated were 13° (stall), 9° (nose up), 5° (intermediate), and 1° (near level). Attitude is defined as the angle between the fuselage deck line and the water surface.

Flaps.- The flap deflections investigated were up, half down, and full down (40°). The flaps on the $\frac{1}{30}$-scale model were held rigidly fixed and semifixed. The flaps on the $\frac{1}{20}$-scale model were held semifixed and scale strength. For the semifixed flaps, the hinges were not adjusted to any specific strength but were adjusted with just enough friction to hold the flaps in position until they were struck by the water. The rigidly fixed flaps were locked in position.

The scale strength for the model flaps was derived from full-scale data which stated that the uniform load that would cause full-down flaps to fail was 74 pounds per square foot.

Landing speeds.- The landing speeds used in the tests are listed in table I. They were computed from lift curves (reference 3) using the previously chosen values of attitude and flap setting and a thrust coefficient equal to zero. The ditching runs given in table I were made at approximately the listed speeds, and in all cases the model was airborne when it was ditched.

Condition of simulated damage.- In order to investigate the effect of fuselage damage on the ditching behavior, various parts of the bottom of the fuselage were removed to simulate their failure. (See fig. 7.) The failing load of each part which was used in determining the conditions of simulated damage is tabulated as follows:

	Failing loads (lb/sq ft)
Bomb-bay doors 1 and 4	60
Bomb-bay doors 2 and 3	100
Nose-wheel doors	75

The following conditions of simulated damage were tested:

1. No damage (see fig. 2)

2. Bomb-bay doors removed (see figs. 3 and 4)

3. Bomb-bay doors, nose-wheel doors, and two turret covers removed (see fig. 5)

4. Bomb-bay doors, nose-wheel doors, turret covers, fuselage bulkhead no. 10, and a triangular section of the fuselage bottom just aft of the bulkhead removed (see fig. 6)

The last condition was included as a result of ditching the model at conditions 2 and 3. Bulkhead no. 10 (which closes off the aft end of the bomb bays) broke several times in the ditchings and had to be reinforced. This damage might happen to the full-scale airplane since, if bomb-bay door no. 4 was torn away, bulkhead no. 10 would receive the full impact of the water. If the bulkhead failed, it would probably tear out some of the adjacent fuselage.

RESULTS AND DISCUSSION

General

Summaries of the results of the tests are presented in table I. The symbols used in table I are defined as follows:

b deep run - a run in which the model travels through the water partially submerged and exhibits a tendency to dive although the attitude of the model is nearly level h smooth run - a run in which there is no apparent oscillation about any axis during which the model settles into the water as the forward velocity decreases

o oscillation in roll - an oscillating motion about the longitudinal axis

p porpoising - an undulating motion about the transverse axis in which some part of the model is always in contact with the water

s skipping - an undulating motion about the transverse axis in which the model clears the water surface completely

u trims up - a run in which the attitude of the model increased after contact

Photographs showing the characteristic behavior of the $\frac{1}{20}$-scale model are shown as figure 8. Typical time histories of longitudinal decelerations are given in figure 9. There was little variation between the behaviors of the two models so no distinction will be made in the discussion.

Only laterally level landings are recorded in table I. In a level landing there was no tendency for the model to turn. However, the model usually turned when landed with one wing low.

The behavior of the model was generally good. No violent motions such as diving occurred, and the maximum longitudinal deceleration recorded was about 4g.

Effect of Attitude

Tests at the high and intermediate attitudes usually resulted in smooth runs. (See table I.) At the 1° attitude the model behaved in various ways, depending on the condition of damage. At this attitude the undamaged model trimmed up and either skipped or porpoised, the model with simulated failure of the bomb-bay doors made smooth runs or porpoised, and the model with simulated failure of all the parts (damage condition 4) made deep runs. About 4g maximum deceleration was recorded for this latter condition. (See fig. 9.) Although smooth runs occurred at the 13°, 9°, and 5° attitudes for all conditions of damage, the 13° attitude is not recommended because it is too close to the stall angle. An attitude of 9° would be better than 5° because the slower speed should cause less damage. The 9° attitude corresponds to a ground landing attitude in which the main wheels and tail skid touch the ground simultaneously.

Effect of Simulated Damage

There was a tendency for the undamaged model to trim up at low attitudes, and the tail of the model rode deeply in the water. This tendency appeared to be caused by negative pressure, or suction, on the aft part of the fuselage. The suction was apparent, but in lesser degree, at other attitudes and conditions of damage. Removal of the bomb-bay doors reduced this suction. The fact that the aft bomb-bay door is relatively weak (60 lb/sq ft will cause failure) means that this door will probably be torn away in a ditching and any tendency of the airplane to trim up or skip will be minimized. In model ditchings the elevator or stabilizer was occasionally damaged. This damage had no apparent effect on the ditching behavior.

The length of run for ditchings with simulated failure of the bomb-bay doors averaged 1 or 2 fuselage lengths less than ditchings with no simulated damage; the model also ran deeper. There was little difference in behavior between damage conditions 2, 3, and 4. Figures 9(a) and 9(b) show the similarity between the time history of deceleration curves for damage conditions 3 and 4.

The forward cabin seems preferable to the aft cabin for a ditching station since at high and medium attitudes the initial impact with the water will be in the vicinity of the aft cabin. Also, if the aft bomb-bay door failed, bulkhead no. 10 (the forward pressure bulkhead of the aft cabin) might fail since it would be subject to direct water forces. The forward cabin usually rides high and remains clear of the water during the early part of the run. Any tail suction that might occur would be an advantage to the forward cabin as a ditching station but a disadvantage to the aft cabin.

Effect of Flaps

Full-down flaps, when held either semifixed or scale strength, and half-down flaps, when held semifixed, were forced to the up position by the water pressure. Smooth runs were obtained for all these flap conditions and with the flaps up. When the full-down flaps were held rigidly fixed, slight porpoising and oscillations in roll were obtained. Since it was found that full-down, scale-strength flaps were weak enough to fail upon contact with the water without causing ill effects on the ditching behavior, it is recommended that the airplane be ditched with full-down flaps so as to obtain low landing speeds.

CONCLUSIONS

From the results of tests of $\frac{1}{30}$-scale and $\frac{1}{20}$-scale models of the B-36 airplane the following conclusions were drawn:

1. The airplane should be ditched at an attitude of about 9° with flaps full down.

2. The probable ditching behavior will be a smooth run with a maximum longitudinal deceleration of 3g to 4g and a landing run of 4 to 5 fuselage lengths.

3. Structural failure of the underside of the fuselage will not seriously affect the behavior of the airplane.

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1. Fisher, Lloyd J., and Steiner, Margaret F.: Ditching Tests with a 1/12-Size Model of the Army B-26 Airplane in NACA Tank No. 2 and on an Outdoor Catapult. NACA MR, Aug. 15, 1944.

2. Jarvis, George A., and Tarshis, Robert P.: Ditching Tests with $\frac{1}{20}$-Size Models of the Army B-29 Airplane in Langley Tank No. 2 and from an Outdoor Catapult. NACA MR No. L6B04, Army Air Forces, 1946.

3. Pepper, Edward, and Furlong, G. Chester: Tests of a 1/14-Scale Powered Model of the XB-36 Airplane in the Langley 19-Foot Pressure Tunnel. II - Longitudinal Stability and Control and Drag Characteristics. NACA MR No. L5D23, Army Air Forces, 1945.

TABLE I. - SUMMARY OF RESULTS OF DITCHING TESTS OF $\frac{1}{30}$-SCALE AND $\frac{1}{20}$-SCALE MODELS OF THE ARMY B-36 AIRPLANE IN SMOOTH WATER

[Gross weight 255,000 lb; all values are full scale]

Landing attitude, deg		13						9							5				1		
Landing speed, mph		100		108		124		110			119		137		122		137		143		
Parts removed to simulate their failure	Flaps / Behavior[1]	Run	Mo	Run	Mo	Run	Mo	Run	Mo	Max	Run	Mo	Run	Mo	Run	Mo	Run	Mo	Run	Mo	Max
$\frac{1}{30}$ - scale model																					
No parts removed (No simulated damage)	Up					6	p						4	h							
	Half-down, semifixed			3	h						2	h					4	up			
	Full-down, fixed	5	po					6	p						6	p			6	uop up	
	Full-down, semifixed	4	h					6	h						4	h			6	u us	
Bomb-bay doors	Up					2	h						2	h							
	Full-down, fixed	4	po					4	po						4	o			4	p	
	Full-down, semifixed	4	h					4	h						4	h			3	h	
$\frac{1}{20}$ - scale model																					
Bomb-bay doors	Full-down, semifixed								h											h	
Bomb-bay doors, nose-wheel doors, turret covers	Up													h							
	Full-down, scale-strength								h	2.3										h	
Bomb-bay doors, nose-wheel doors, turret covers, bulkhead no. 10, triangular section	Full-down, scale-strength								h	2.0										b	3.9

[1]Behavior:
Run - Length of landing run, given in multiples of the length of the airplane.
Max - Maximum deceleration, given in multiples of the acceleration of gravity.
Mo - Motion of the model, denoted by the following symbols:
- b - ran deeply
- h - ran smoothly
- o - oscillated in roll slightly
- p - porpoised slightly
- s - skipped
- u - trimmed up

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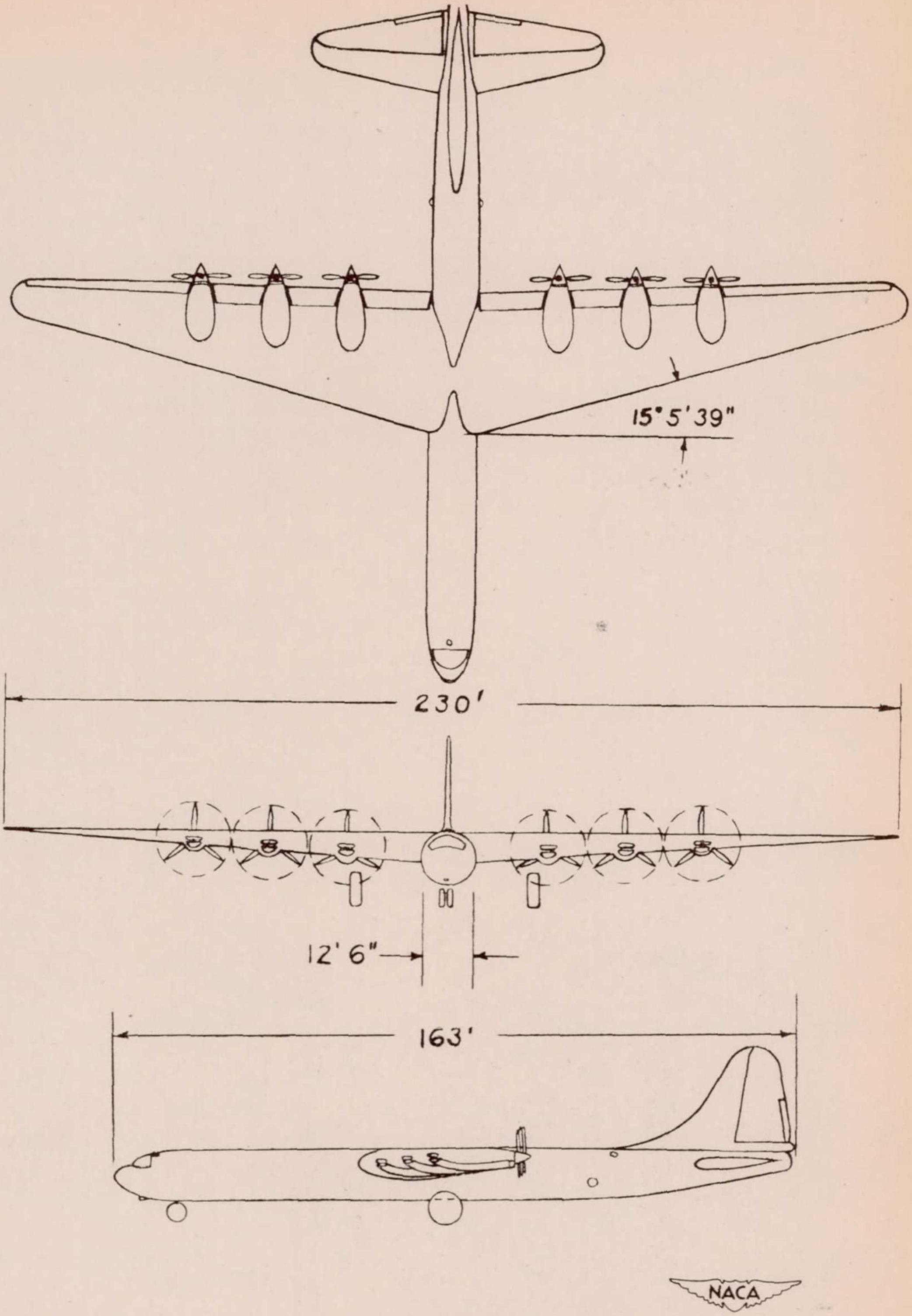
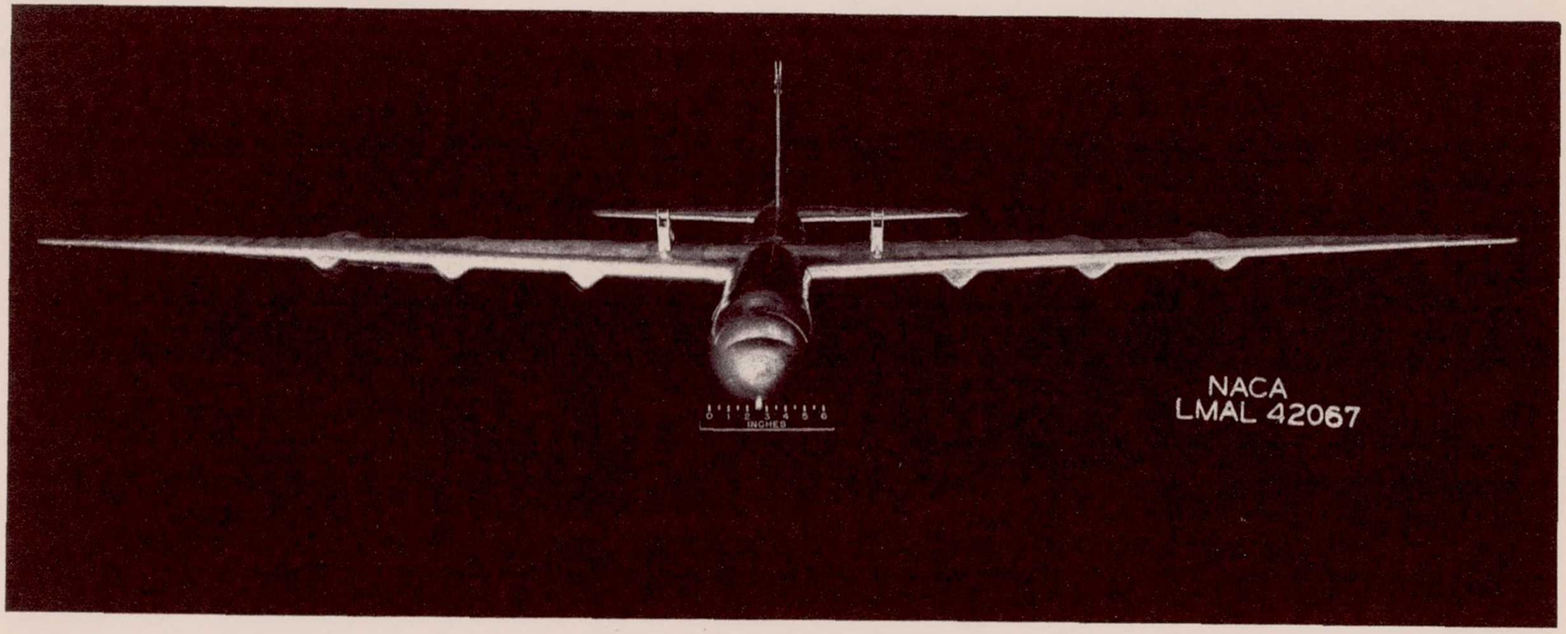


Figure 1. - Three-view drawing of the Army B-36 airplane.



(a) Front view.

Figure 2.- Photograph of $\frac{1}{30}$-scale model of the B-36 airplane with no simulated damage.

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(b) Side view.

Figure 2.- Continued.

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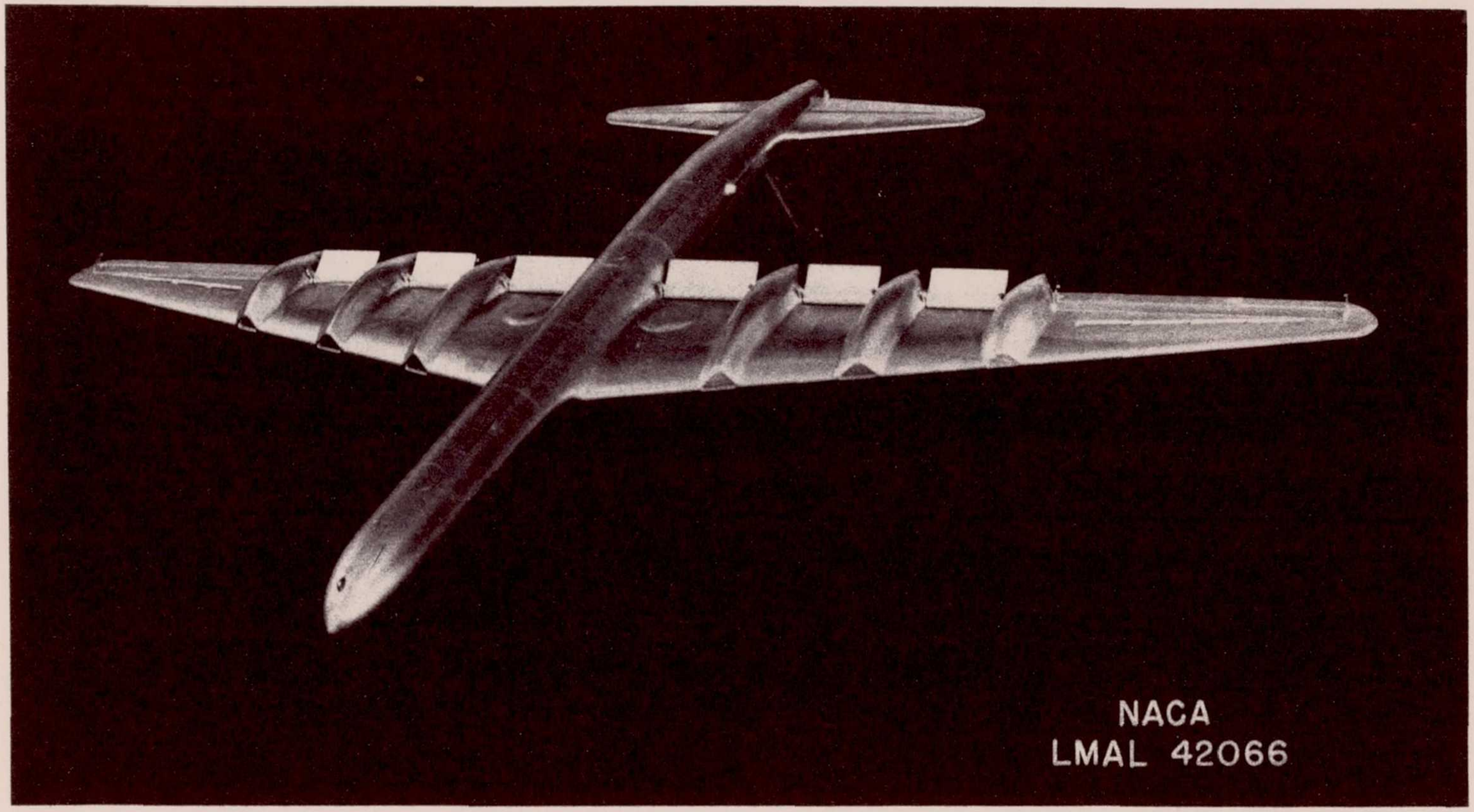

(c) Three-quarter bottom view.

Figure 2.- Concluded.

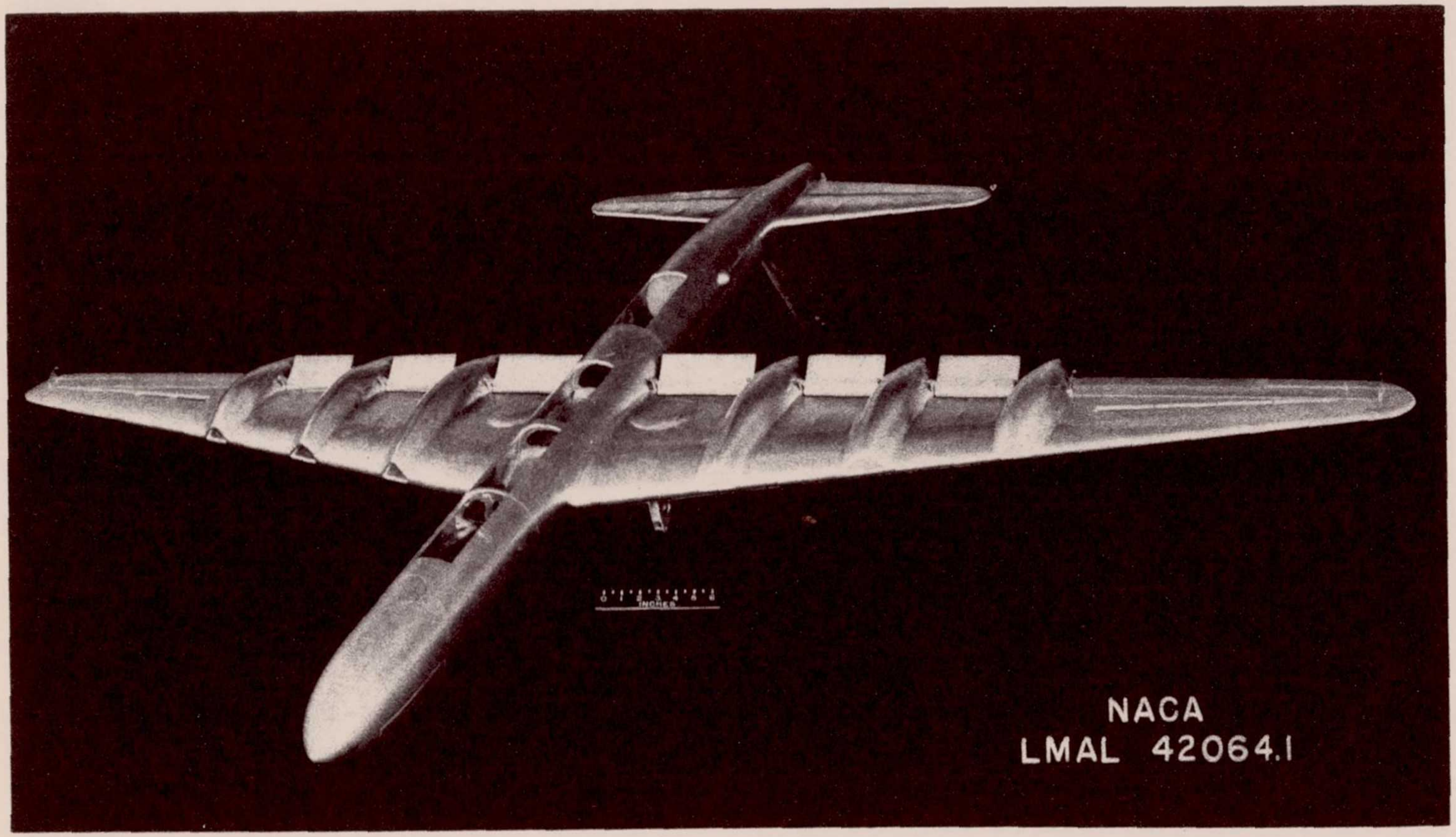

Figure 3.- Photograph of $\frac{1}{30}$-scale model of the B-36 airplane with simulated failure of the bomb-bay doors.

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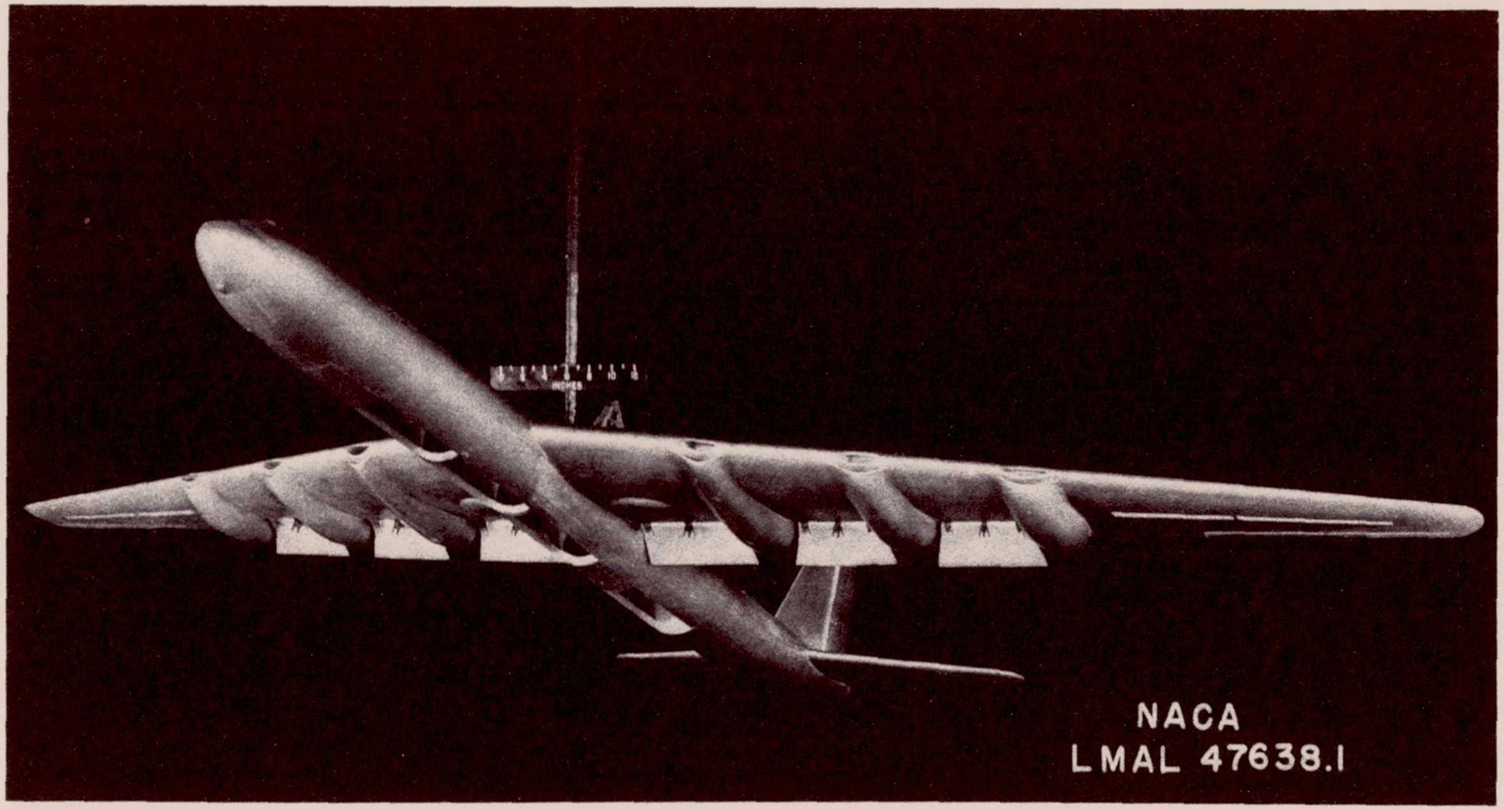

Figure 4.- Photograph of $\frac{1}{20}$-scale model of the B-36 airplane with simulated failure of the bomb-bay doors.

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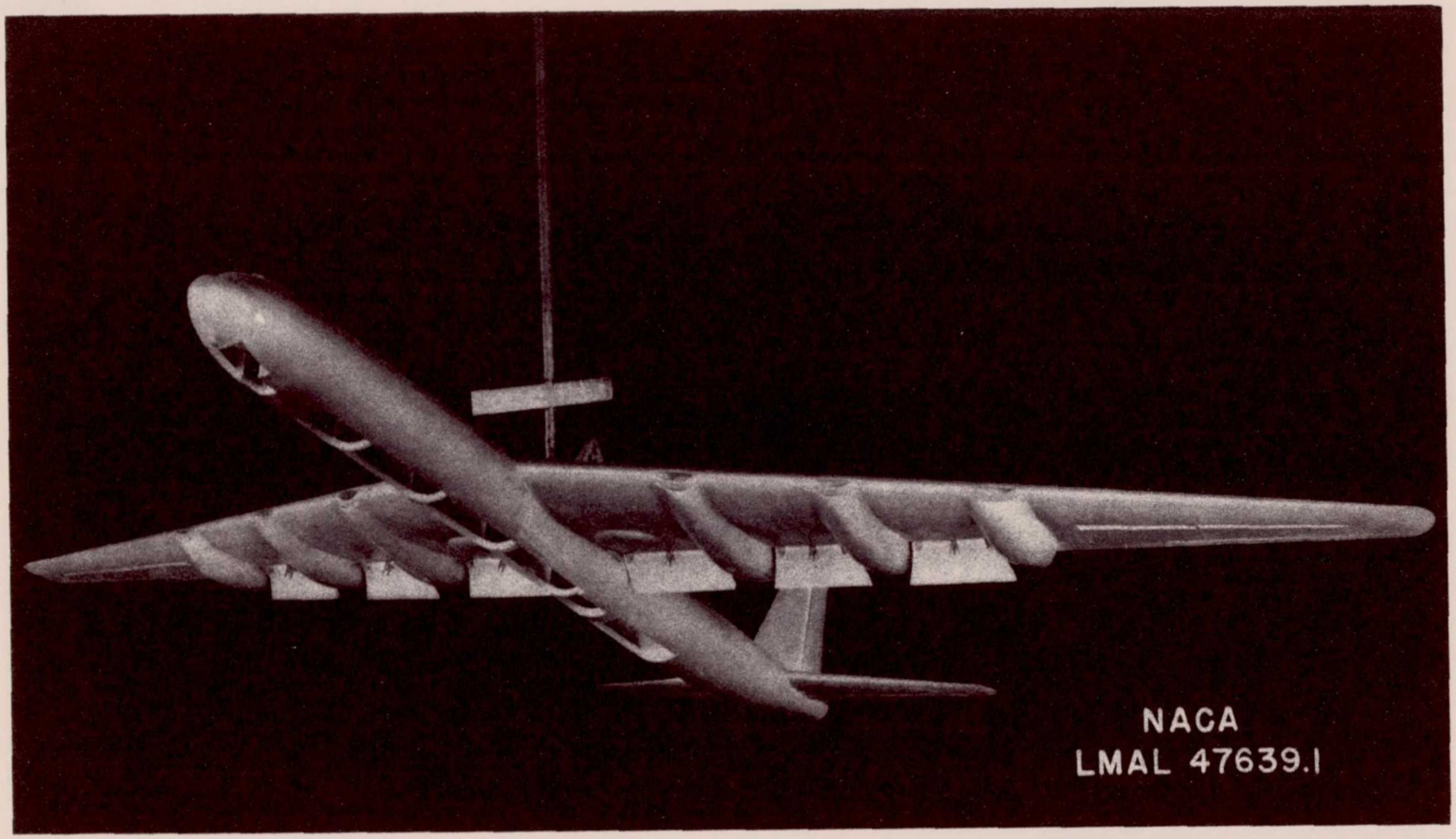

Figure 5.- Photograph of $\frac{1}{20}$-scale model of the B-36 airplane with simulated failure of the nose-wheel doors, bomb-bay doors, and turret covers.

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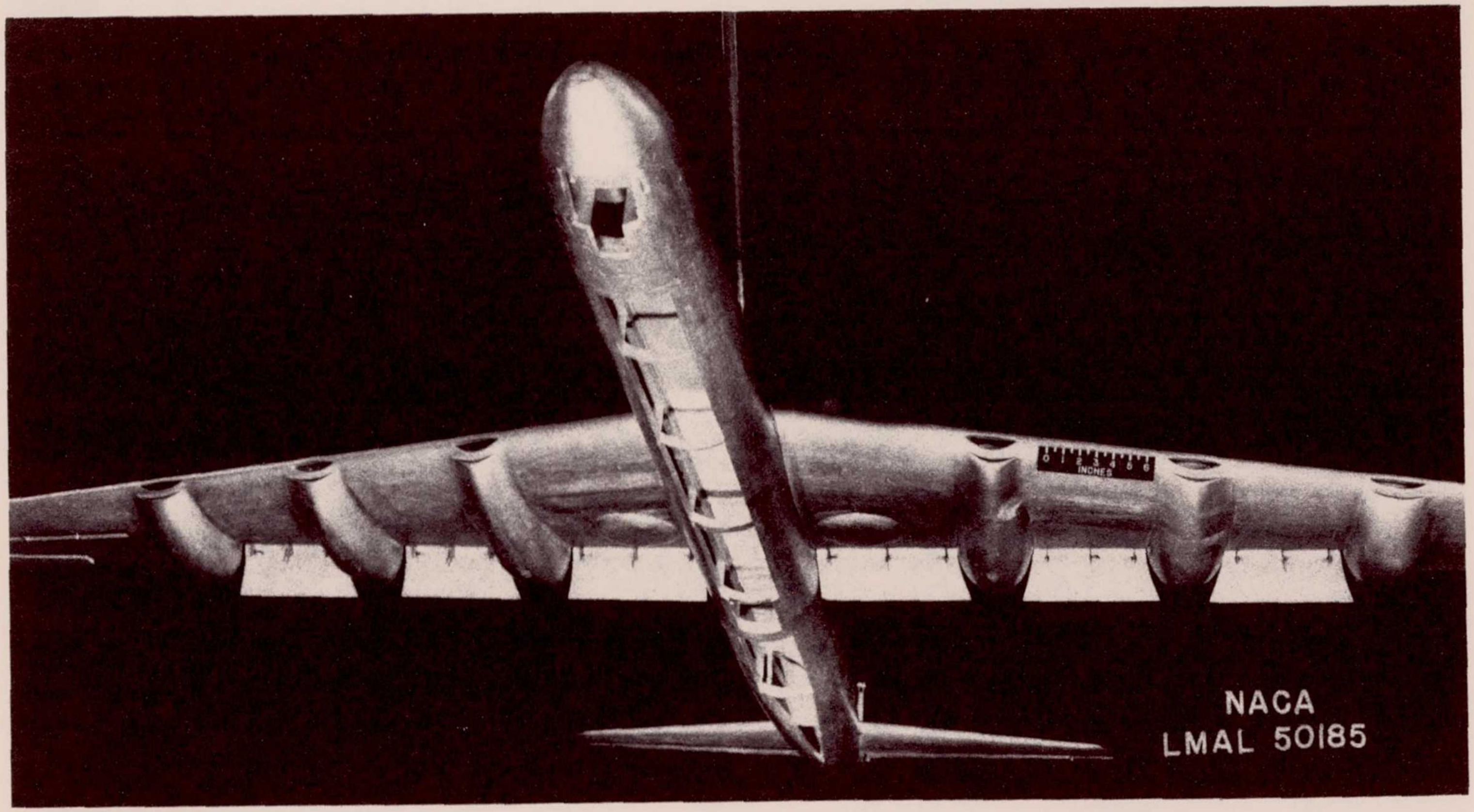

Figure 6.- Photograph of $\frac{1}{20}$-scale model of the B-36 airplane with simulated failure of the nose-wheel doors, bomb-bay doors, turret covers, bulkhead no. 10, and triangular section.

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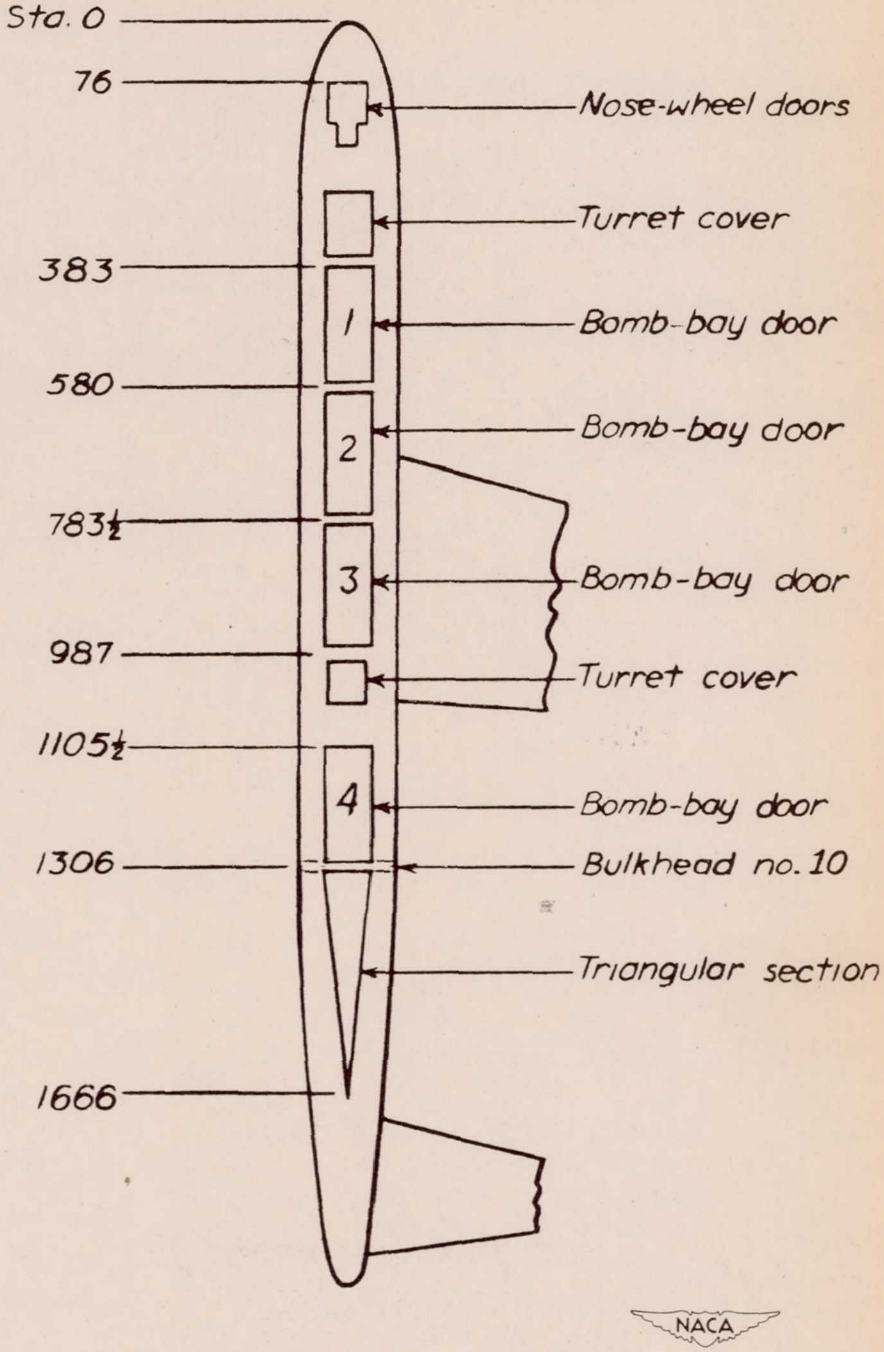
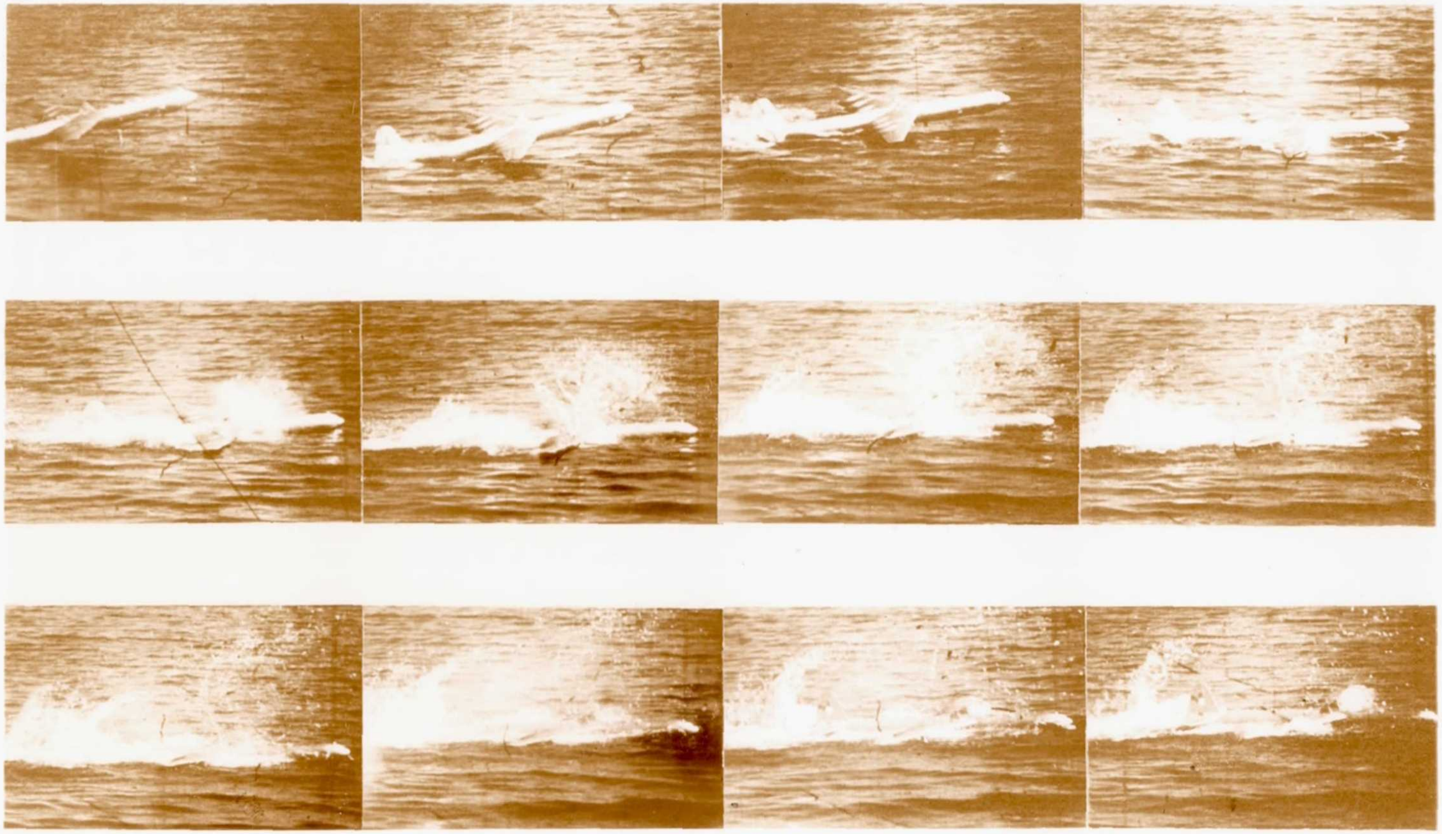
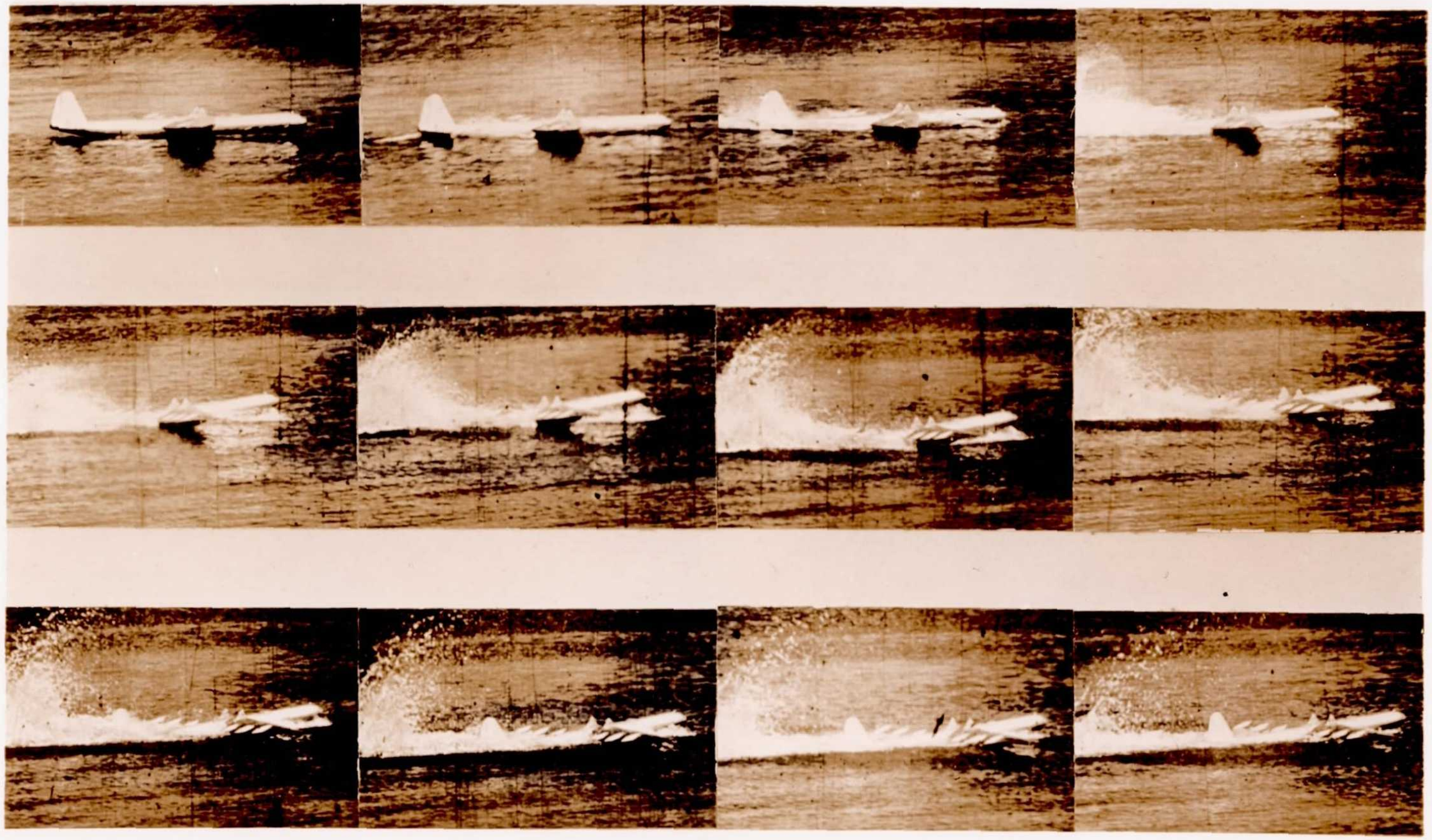


Figure 7. - Bottom view of fuselage showing the components removed to simulate their failure.



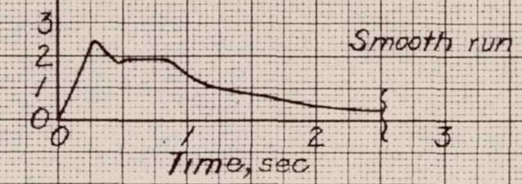
(a) Landing attitude, 9°; landing speed, 110 mph.

Figure 8.- Sequence photographs at 0.55-second intervals of a $\frac{1}{20}$-scale model of the B-36 airplane with simulated failure of the nose-wheel doors, bomb-bay doors and turret covers, and with full-down scale-strength flaps. (All values are full scale.)

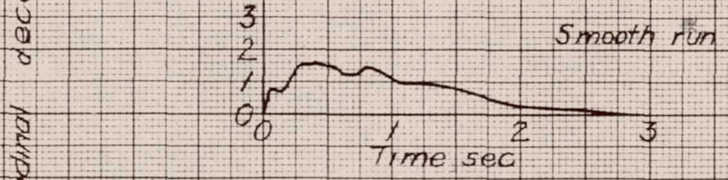


(b) Landing attitude, 1°; landing speed, 125 mph.

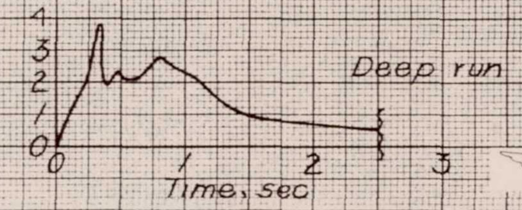
Figure 8.- Concluded.



(a) Landing attitude, 9°; landing speed, 110 mph. Simulated failure of nose-wheel doors, bomb-bay doors, and turret covers.



(b) Landing attitude, 9°; landing speed, 110 mph. Simulated failure of nose-wheel doors, bomb-bay doors, turret covers, bulkhead no. 10, and triangular section.



(c) Landing attitude, 1°; landing speed, 135 mph. Simulated failure of nose-wheel doors, bomb-bay doors, turret covers, bulkhead no. 10, and triangular section.

Figure 9.- Typical time histories of longitudinal decelerations for ditching tests of a $\frac{1}{20}$-scale model of the B-36 airplane with full-down scale-strength flaps. (All values are full scale)